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A GUIDE
TO THE
FOSSIL INVERTEBRATE
ANIMALS

IN THE DEPARTMENT OF
GEOLOGY AND PALAEOLOGY
IN THE
BRITISH MUSEUM (NATURAL HISTORY),
CROMWELL ROAD, LOND N. S.W.

WITH 7 PLATES AND 96 TEXT-FIGURES.

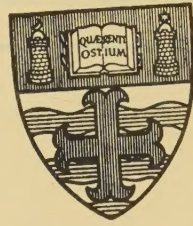


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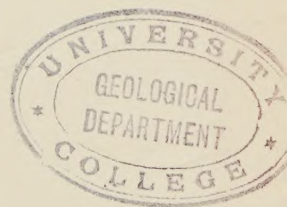
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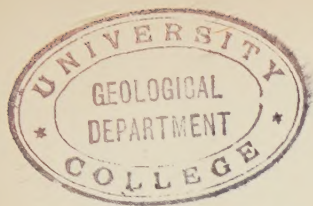


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PREFACE.

THE "Guide to the Fossil Invertebrates and Plants" having run out of print, it is in part replaced by this book dealing with the Invertebrate Animals, while it is proposed that the Fossil Plants shall form the subject of a separate Guide. By describing the Galleries and their contents in a different order from that followed in the previous Guide, it is attempted to present the whole as a connected story. At the same time the book does not profess to be a complete systematic treatise, but relates only to the specimens actually exhibited in the Galleries.

As in the other Guides to the fossil animals, the present one assumes on the part of the reader at least so much knowledge of the existing world of life as is conveyed by the corresponding Guides to the Department of Zoology. Since, however, many of the groups of animals herein dealt with are entirely or almost entirely extinct (e.g. Graptolites, Cystids, Trilobites, Ammonites), they have been treated more fully than those which are more familiar.

The First Edition of this Guide, published in 1907, was written by Dr. Francis Arthur Bather, Assistant Keeper of Geology, who also has carefully revised the book for this, the Second Edition. Alterations, necessitated by the advance of science, by additions to the exhibited specimens, or by changes in the arrangement of the Galleries, have been made in every section. Figures 41, 49 and 65*a* have been replaced by new and better ones.

In preparing the work, help was received from Mr. R. Bullen Newton and Mr. G. C. Crick in connection with the Mollusca; from Mr. W. D. Lang in connection with the Bryozoa and Coelentera; and from Dr. W. T. Calman in connection with the Arthropoda. Dr. Bather wishes to acknowledge the valuable aid of the same colleagues, and of Mr. T. H. Withers in checking the text for this edition.

Thanks are also due, for similar assistance, to Mr. S. S. Buckman, Mr. H. W. Burrows, Mr. C. D. Sherborn, and Mr. B. B. Woodward. For permission to use copyright illustrations the Trustees are indebted to Messrs. A. & C. Black, Messrs. Archibald Constable & Co., Messrs. Longmans & Co., the Cambridge University Press, the Council of the Geological Society, and Dr. Henry Woodward, F.R.S. (Editor of the Geological Magazine).

A. SMITH WOODWARD,
Keeper of Geology.

DEPARTMENT OF GEOLOGY.
Oct. 1911.

A GUIDE

TO THE

FOSSIL INVERTEBRATE ANIMALS.

THIS book is a guide to the fossil remains of Invertebrate Animals and to a few subsidiary collections contained in Galleries Nos. VII, VIII, X, and XI of the Geological Department. These Galleries may be approached by turning to the left, either immediately on entering the large Gallery of fossil Mammals, or on reaching the end of it. Both these turns to the left lead into the long Gallery No. IV containing fossil Reptiles, out of which lead the four Galleries here described (See Frontispiece-Plan, Plate I).

Gallery VII is the westernmost and is nearest the main entrance, and Gallery XI is furthest away, towards the east. The entrance to each Gallery is at its south end. The Wall-cases and Table-cases in the Galleries are numbered consecutively, No. 1 being, in the wider Galleries, on the left hand of the visitor as he enters, and the highest number being on his right. Following this order of the Cases, the contents of these Galleries are briefly as follows:—

Gallery VII: Cephalopods (Ammonites, Belemnites, &c.).

Gallery VIII: All Molluscs (except Cephalopods), Bryozoa, Brachiopods, Arthropods (insects, lobsters, trilobites, &c.), ringed worms, Echinoderms (sea-urchins, star-fishes, &c.).

[Gallery IX: Geological Library and Students' Collection, closed to the public.]

Gallery X: Coelentera (corals, graptolites, &c.), Sponges, Protozoa, Plants (these last to be described in a separate Guide-book).

Gallery XI: Stratigraphical series of rocks and fossils; Forms and Structures produced by geological agents, and in some cases simulating fossils; Tracks and Footprints left by various animals; and Collections of Historical interest.

For the purposes of this Guide, it is more convenient to take the collections in the reverse order from that given above, namely, to begin with Gallery XI. The description of the specimens exhibited in that Gallery serves to explain the meaning of fossils and the use made of them in interpreting the structure and history of the earth. We then proceed to Galleries X, VIII, and VII, beginning with the simplest forms of life and passing gradually to those more highly organised. Under each group of animals too, the description generally begins with the older fossils and traces the history of the group down to our own day. In order to follow this method of description, it is, in Galleries X and VIII, necessary to visit the Cases in the reverse order of their numbering.

The collections in Galleries X, VIII, and VII are arranged, in the main, according to a zoological classification, the specimens belonging to the various large groups of the Animal Kingdom being placed together. In some groups it has been found more convenient to subdivide the specimens according to the geological epochs to which they belong, and under each of those epochs again to arrange them in zoological order. In other groups the zoological system is the dominant one throughout, all species of each genus being placed together. It is also the general rule that the specimens from British localities are exhibited in the Table-cases, and those from foreign localities in the Wall-cases. This, however, is not rigidly adhered to; for example, among the larger specimens mounted on blocks and placed usually towards the back of the Wall-cases may often be found several British specimens, which have to be exhibited there on account of their size.

Although all the animals whose fossil remains are herein described are often spoken of collectively as Invertebrata, or backbone-less animals, in contrast to the Vertebrata, or animals with a backbone, yet it must be remembered that this common usage does not represent a scientific classification. It is nearer the truth to say that each of the larger groups named above—Mollusca, Arthropoda, Echinoderma, Coelentera, and the rest—has the same independence and importance as a division of the Animal Kingdom as has the whole group of Vertebrata. Just as the Vertebrata are divided into Classes, namely, Mammals, Birds, Reptiles, Amphibians, and Fishes, so is each of these great groups, or Phyla as they are termed, divided into Classes. Each Class

is again divided into Orders, and sometimes Sub-Orders, and each of these into Families. The names of the Orders are usually printed in large type on cards fixed in the Exhibition Cases. The names of the Families are printed on labels mounted on wood and inserted in their places in the series; they may be recognised by always ending in *-idae*. The Families again are divided into Genera, each composed of a number of allied Species. The generic names are printed and mounted on wood in similar fashion to the family-names.

The names on the labels of the separate specimens consist of the name of the genus (e.g. *Conchidium*) followed by the trivial name (e.g. *biloculare*), the two together making up the name of the species. This is followed by the name of the author who first described and named the species, e.g. *Conchidium biloculare*, Linnæus. When the species has been transferred to a genus other than that in which it was placed by the original author, then that author's name is placed within brackets or followed by "sp." Thus Brünnich in 1781 described as *Trilobus caudatus* a trilobite which is now placed in the genus *Dalmanites*; therefore we write *Dalmanites caudatus* (Brünnich). Since 1839, however, this trilobite has generally been placed in the genus *Phacops*, and appears in the text-books as *Phacops caudatus*. In this Guide-book the generic name by which a species is generally known is added within square brackets after the correct name e.g., *Dalmanites* [*Phacops*] *caudatus* (Brünnich). When a genus has been split up into sub-genera, the name of the sub-genus to which a species belongs may be inserted within round brackets between the name of the genus and the trivial name, thus, *Orthis* (*Dalmanella*) *elegantula*.

Many of the exhibited specimens bear small discs of green or red paper. A green disc indicates that the specimen bearing it either is the original specimen on which the species to which it belongs was based (a so-called type-specimen), or has been described and figured in some scientific work, to which a reference is given on the label. Specimens marked with red discs have been merely noticed or briefly described in some published work.

STRATIGRAPHICAL SERIES AND HISTORICAL COLLECTIONS.

Gallery XI. Hanging on the wall of Gallery XI, immediately to the left of the entrance is a diagram showing very broadly the **Geological Epochs** during which the rocks found in Great Britain were formed, the newest being at the top and the oldest at the bottom of the column. A more elaborate list, with the Epochs divided into Ages, is given as a table (facing p. 1) in the present Guide.

Wall-cases 1-5. Adjoining the diagram, in the wall-cases on the west side of the gallery, is the **Stratigraphical Series**, which is a collection of the various kinds of rock found in Britain, arranged in order of age. Along the top of the Cases is a diagram showing the succession of these rocks from the newest to the oldest, as they might be seen in a continuous section across the country from east to west. Examples of the rocks themselves occur on the shelves below, where will also be found numerous small sections of the strata, as observed in various parts of England. Affixed to the Cases is a series of small maps, each coloured to show the tract of country occupied by the one or two rock-groups of which specimens are exhibited in the adjoining Case. In the long section, the numbers placed beneath the beds give their approximate thicknesses in feet. It must not, however, be supposed that all these beds occur in such regular succession right through the country, the fact rather being that one is found in one district, while another is better developed elsewhere, as indeed may often be gathered from the names applied to the beds. Certain gaps in the section, as between Pliocene and Eocene, and again between Permian and the Coal Measures, represent intervals of time, during which there were being deposited rocks, which are found in other parts of the world, but for one reason or another do not occur in the British area.

It is plain that when rocks have been deposited, as we know that they now are being deposited, at the bottom of the sea, then the underlying rocks are older than those above them. As concrete examples of the way in which one layer of rock is found lying on another, there are placed on the floor between the Wall-cases in various parts of the Gallery several examples of the cores of rock brought up from below by **deep borings**. Thus at Dover the boring for coal went down through the Chalk at the surface, through several rocks

**Between
Wall-cases
3 & 4.**

underneath this, till it came to the sandstones of the Coal Measures, of which cores from depths of 1262 feet and 2234 feet are here exhibited, as well as a piece of coal from 2039 feet. At Ware, in Hertfordshire, a boring through the Chalk brought up from a depth of 825 feet the core of Wenlock Shale here shown. At the far end of the Gallery are cores of Carboniferous Limestone obtained beneath the Lower Jurassic rocks close to Northampton, from depths of 805 to 828 feet. We learn from these borings that the rocks found on the surface in the western and north-western parts of England, pass beneath other rocks and stretch under the south-east of England and presumably under the sea until they come again to the surface in Belgium and the north-east of France. Thus we have proof quite easy to understand that in this country the older rocks pass generally from north-west to south-east under newer ones, as shown in the long section at the top of the Wall-cases.

Gallery XI.

Between
Wall-cases
4 & 5.

Among the specimens selected in illustration of the various beds are many containing the remains of animals or of plants. Thus, the very first specimen at the top left-hand corner of Case 1 contains fragments of bone embedded in a stalagmitic deposit which formed on the floor of Brixham Cave : and this indicates that the animals to which the bones belonged lived, or at least died, in the cave, where their remains were gradually covered by the limy deposit. Close by is a piece of an old beach from Brighton, in which is embedded part of a horse's leg-bone. Below these are other specimens of beach-deposits, in which may be seen the remains of shells. Lower down in the Case are rocks of more sandy nature, such as are now being formed off shore, and in them also may be seen shells, as well as the remains of other marine animals and plants. These either lived at the bottom of the sea or sank to it when dead, and were then gradually covered by sand or clay produced by the wearing of the land and deposited on the sea-floor. All such remains or traces of animals and plants found in the rocks are called **fossils**.

Wall-case
1.

Although the specimens exhibited in this series are not intended to give anything like a complete idea of the animals living in former periods of the earth's history, still as the visitor passes down the Gallery, he will readily observe that the fossils contained in the fragments of rock gradually change in character. Those in the first Case are, as has been seen, similar to animals living at the present day ; but

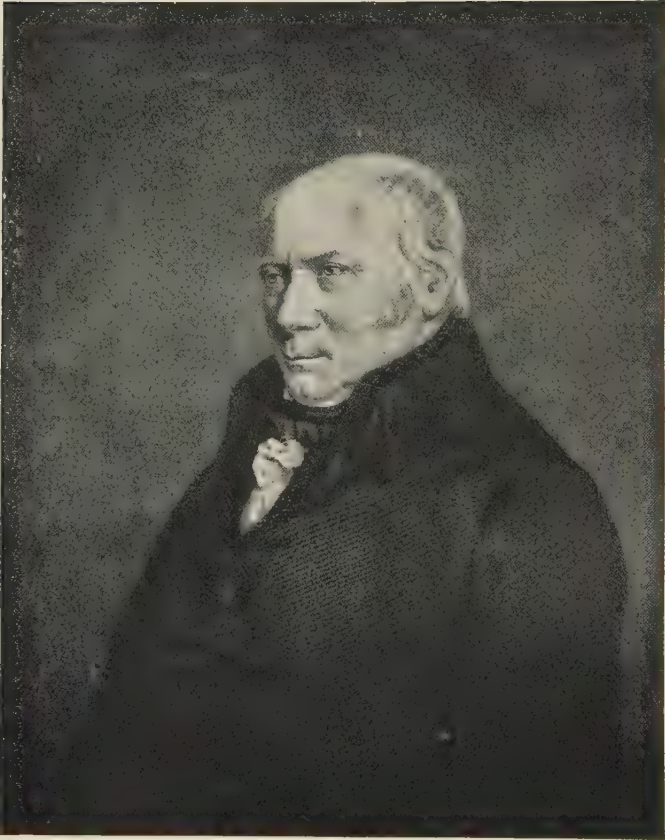
Gallery XI.
Wall-cases
2, 3.

Wall-cases
4, 5.

Between
Wall-cases
10 & 11.

already in Case 2, where are exhibited specimens from the Chalk, many forms have an unfamiliar appearance, and indeed belong to types of life which no longer exist. A like strangeness characterises the Jurassic fossils, but is still more noticeable among the older rocks: thus Case 4 contains some of the curious plants from the Coal Measures, while in Case 5 are fragments of Old Red Sandstone with the strange fishes characteristic of that period. Closer inspection would show that this change was gradual and continuous, and that each of the successive beds of rock was characterised by fossils differing from those found in the beds above and below. Sometimes the bed itself may change in mineralogical character, while the fossils remain the same. Therefore, when once a geologist knows the fossils characteristic of the various strata he can, if set down in any part of the country, readily determine on which bed in the geological series he is standing, if only he can find a few fossils.

The credit of first recognising this important fact is due, at least so far as British geology is concerned, to **William Smith** (Plate II), whose bust, a copy of that by Chantrey in All Saints' Church, Northampton, is on the eastern wall of the Gallery. The son of a small farmer and mechanic, Smith was born at Churchill, Oxfordshire, in 1769, and at an early age collected the fossils that occur in the rocks around his home. When the boy was eight years old his father died, leaving him to the care of an uncle who, noticing the studious habits of his nephew, gave him some money to buy books. By means of these he taught himself to such purpose that at the age of eighteen he obtained employment as a land surveyor in Oxfordshire and the neighbouring counties and, in 1793, was appointed to survey the course of the intended Somersetshire coal canal near Bath. Six years' work on this canal, added to his previous knowledge, enabled him to prove that the strata met with in this district followed each other in a regular and orderly succession, each bed being marked by its own characteristic fossils, and having a general tendency to slope or dip to the S.E. That this succession was no local phenomenon, and that the same fossils were throughout characteristic of the same beds, was subsequently proved by Smith in his journeyings over the greater part of Britain. The surveys made on these journeyings enabled him, in 1815, to publish the large map exhibited on the right hand of the entrance to this Gallery. This, the first geological map of England



Wm Smith L.L.D
aged 69.

and Wales, comprising also a part of Scotland, measures 8 feet 9 inches by 6 feet 2 inches. Several sections across England, published by Smith in 1819, are placed on the wall around his bust. Here also are reproductions of the first small sketch for the larger map coloured by him in 1801, of a map of the country around Bath coloured geologically by him in 1799, and of a table of strata dictated by him in the same year.* The original MSS. of these were presented by Smith to the Geological Society in 1831. Gallery XI.

Smith's views on the value of fossils to the geologist and surveyor were enunciated in his works "Strata identified by organised fossils," of which four parts only were published (4to, 1816-1819), and "Stratigraphical system of organised fossils" (4to, 1817). A set of the plates from the former work is exhibited in the Case below Smith's bust and in a frame on the adjoining wall. The different colours to the backgrounds of the plates are the same as those employed by Smith in his geological map, and have continued in general use, with many of our common geological names for British formations, such as Lias, Greensand, Coral Rag, and Cornbrash, all of which were adopted by him from the local terms in use by quarrymen and others. The fossils illustrated in these works, with many others collected by Smith, are contained in the same cabinet, and form the most characteristic memorial of one who was justly termed by Adam Sedgwick "the father of English geology."

Besides the William Smith Collection, acquired by the Trustees in 1816 and 1818, there are arranged in the Table-cases of this Gallery eight other collections of special interest as bearing either on the early history of the British Museum or the study of geology and palaeontology in this country.

At the end of the Gallery will be found the oldest and, in some respects, the most interesting of these, under the heading **The Sloane Collection**. Here are still retained in their old association just one hundred specimens out of the large series that once formed the museum of Sir Hans Sloane (1660-1753), who by the terms of his will, may be considered the first founder of the British Museum, since he offered his collection to the nation for the relatively small sum of £20,000, in order "that it might be preserved and maintained, not only for the inspection and entertainment of the learned and the curious, but for the general use and benefit of the Table-case
16.

* See J. W. Judd: "William Smith's Manuscript Maps," Geological Magazine, 1897, p. 439.

Gallery XI. public to all posterity." The collection was purchased on these terms in 1753, and the British Museum, then in Montagu House, Bloomsbury, was opened to the public in 1759. The geological portion contained many thousand specimens of minerals and of "extraneous fossils, comprehending petrified bodies, as trees, or parts of them, herbaceous plants, animal substances," and the like. It included the large collections previously formed by William Courten (1642-1702) and James Petiver (1658-1718). In 1857 the minerals were removed from the collection to the newly instituted Department of Minerals, and it is only the "extraneous fossils" that are now preserved in the Geological Department. Each specimen in the Sloane Collection had originally a number attached to it, corresponding to a carefully prepared MS. catalogue, still preserved in the library of this Department, and containing many curious entries concerning the various objects. In the course of over a century and a half many of the labels have become detached from the objects, or obliterated by cleaning, so that although other specimens from the Sloane Collection may be in the Department, it is no longer possible to identify them, and even among those here gathered together, there are some which cannot be referred to their original entry. So far as possible, however, the original words applied to the specimens by Sloane himself have been reproduced on the label, and thus the collection is of particular interest as showing the way in which such specimens were regarded by an eminent naturalist in the early part of the eighteenth century, and throws some light upon various names now disused, but then generally employed by scientific writers. Among the specimens attention may be directed to the chambered portion or phragmocone of a belemnite brought from Japan by Engelbrecht Kaempfer, some Echinites or fossil sea-urchins from Dr. Lavater, a coral from Mr. Beaumont, F.R.S., and especially the Echinites from Agostino Scilla's Collection. Scilla was a Sicilian painter, who in 1670 published an important book on fossils. By these specimens the Museum is connected with some of the famous collections in the early history of geology.

Table-case
16.

Adjoining the Sloane Collection, and in the same Table-case, is a collection of 124 Tertiary fossil shells obtained by **Gustavus Brander** (1720-1787) from the cliffs of Barton in Hampshire, and presented by him to the Museum in 1765. The collection was described by D. C. Solander, an officer of the Museum, in a work entitled, "Fossilia Hantoniensia

collecta, et in Musaeo Britannico deposita a Gustavo Gallery XI. Brander," London, 1766. The specimens retain the original names given by Solander, underneath which are the names now in general use. Those figured in the book are distinguished by a disc of green paper, as previously explained (p. 3).

The miscellaneous assemblage of specimens figured in **Koenig's** "Icones fossilium sectiles" (1820, 1825), and the collection of fossils from the Carboniferous Limestone of Bolland, formed by **William Gilbertson** of Preston, both of which were formerly exhibited here, have now been dispersed among the systematic series.

The next collection, from which only a selection is exhibited, was formed by a naturalist who devoted his entire life to the study and illustration of a single class of organisms, namely, the Brachiopoda. This was **Thomas Davidson** (1817-1885), whose great monograph on the British fossil Brachiopoda was published by the Palaeontographical Society between 1850 and 1886. The collection contains many of the specimens therein described, as well as an excellent series from foreign localities; it also includes the specimens described in Davidson's Monograph of recent Brachiopoda (Trans. Linnean Soc. 1886-1887). The entire collection of 22,831 specimens was bequeathed by him to the Trustees of the British Museum and handed over by his son, William Davidson, Esquire, in 1886, with Davidson's original drawings, and his library relating to the subject. As an attempt to reduce the inconvenience caused to students by the retention of these specimens apart from the general series of Brachiopoda in Gallery VIII (p. 108), most of the other type-specimens and figured specimens have also been removed from their systematic position or from other collections, and have been mingled with the exhibited brachiopods of the Davidson collection.

Table-cases
13, 14, 15,
16.

The next three Table-cases contain the greater part of the collection which formed the basis of the "Mineral Conchology of Great Britain," a work by **James Sowerby** (1757-1822) and his son, James de Carle Sowerby, of which successive parts, issued between June, 1812, and January, 1846, amounted to seven volumes in 8vo, illustrated with 648 plates, engraved by the authors and, in some of the later parts by G. B. Sowerby and by J. W. Salter, afterwards Palaeontologist to the Geological Survey. The collection comprises about 5000 fossils, from all parts of England and

Table-cases
10, 11, 12.

Gallery XI. from every geological formation, many of them named and described for the first time in the "Mineral Conchology," and therefore the type-specimens of the species to which they are referred. Many of the green discs indicating figured specimens were actually fixed by James Sowerby. The ammonites and cirripedes of this collection have been removed to their respective positions in the general systematic series in Galleries VII and VIII (see pp. 167 and 94). The collection was purchased by the Trustees of the Museum from Mr. J. de Carle Sowerby in 1861.

Table-cases 10, 11, 12. The two collections which follow owe their inception to a society known as The London Clay Club, founded in 1838 by a few London geologists—namely, J. S. Bowerbank, Searles V. Wood, John Morris, Alfred S. White, Nathaniel Wetherell, J. de Carle Sowerby, and F. E. Edwards. Originally intending to illustrate the British Eocene Mollusca, they eventually in 1847 founded the Palæontographical Society for the purpose of monographing all the fossils of the British Isles. Here is exhibited the collection of Eocene Mollusca, begun by **Frederick E. Edwards** (1799–1875) about 1835, and continually increased until a few years before his death. It was purchased by the nation in 1873. Starting with the fossils of the London Clay, Edwards extended his researches to the Eocene strata of Sussex, Hampshire, and the Isle of Wight, where he was assisted by Mr. Henry Keeping. This collection served as the basis of six memoirs contributed to the monographs of the Palæontographical Society, 1848–56, and of various other papers published by him. The Eocene bivalves in the collection were described by Searles V. Wood in the volumes of the Palæontographical Society for 1859, 1862, 1870, 1877. About 500 species were thus described and figured, but the collection also contains many new and undescribed forms to which manuscript names were applied by Edwards. A catalogue of the collection, by Mr. R. Bullen Newton, was published by the Trustees in 1891.

Table-cases 3-9. The first publication of the Palæontographical Society was Part I. of the "Crag Mollusca"—a monograph by **Searles V. Wood** (1798–1880), published between the years 1848 and 1861, with supplements in 1871, 1873, and 1879. The collection on which this work was based was begun in 1826, and took about thirty years to form. It represents the Molluscan fauna of the Red and Coralline Craggs of the neighbourhood of Woodbridge, and from Ald-

Table-cases 1, 2, 3.

borough, Chillesford, Sudbourn, Orford, Butley, Sutton, Ramsholt, Felixstowe, and many other localities in Suffolk, also from Walton-on-the-Naze in Essex. The collection was presented by Mr. Wood to the British Museum in 1852, and a supplementary collection was given by Mrs. S. V. Wood, jun., in 1885.

Gallery XI.
Table-cases
1, 2, 3.

Before leaving these collections, the visitor may again be reminded that their importance lies in the fact that they contain the specimens described in certain classical memoirs, and form therefore the ultimate evidence for the truth of these works. This is particularly the case when a student wishes to make certain of the actual form which was in the mind of the original author when he was describing a new species. Owing to the subsequent discovery of many closely related and intermediate forms, it is usually impossible for a species founded by the older writers to be recognised from their descriptions and figures alone. The specimens themselves must be seen. Consequently these original or type-specimens, as they are called, are of the highest importance in scientific study. A very large number of type-specimens in the various groups of fossils are preserved, and most of them exhibited, in the general collection of the Department, where they may be readily found in their proper zoological and geological positions. The similar specimens in this gallery have been kept apart, either owing to the historical interest of the original collections, or in deference to the wishes of their former owners.

For more complete information concerning the numerous collections of fossils that have found their way into the British Museum, reference should be made to "The History of the Collections contained in the Natural History Departments of the British Museum," vol. i, 1904.

DYNAMICAL SERIES; TRACKS AND MARKINGS.

Gallery XI.

At the further end of the Gallery are exhibited several illustrations of forms produced by natural agencies, as a rule unconnected with animal or vegetable life, and yet frequently simulating fossil organisms. Some of these illustrate the **greater geological agents**. The kind of movement that takes place in mountain building is shown by some models constructed by Lord Avebury and presented by him (see Quart. Journ. Geological Society, lix, p. 348, and lxi, p. 345). Movements of this kind naturally crumple and contort the rocks, and fragments bent and folded in this way are exhibited in the adjoining Wall-case. Besides crumpling, there is a shearing action, and in some of the slates may be observed trilobites greatly distorted, proving the considerable movement that the particles of rock have undergone. The specimens of "ruin marble" below are also due to slight cracks and displacements of the original rock-bands, a phenomenon even more clearly exemplified in a brightly coloured rock from Johannesburg. The "landscape marble" underneath, also probably owes its origin to subsequent disturbance of the original strata, in some cases perhaps combined with the action of organisms. Earth-movements acting on less compact rocks, such as those containing pebbles or boulders, frequently produce a striation and faceting of the stones, as exemplified in some curiously faceted pebbles of Carboniferous age found in the Punjab. One of these is here exhibited. Beside it are boulders or pebbles polished or striated or faceted, either by the action of ice or by that of wind-blown sand, or even by animals rubbing against them. There are also shown examples of rock-weathering by other agencies, such as atmospheric weathering, and borings by land-shells, sea-shells such as *Pholas* and *Saxicava*, worms, sponges, white ants, and other organisms. Among these specimens the most interesting is a portion of one of the columns of the temple of Jupiter Serapis at Puzzuoli, familiar to all readers of Lyell's "Principles of Geology." The marble has been perforated by boring marine shells (*Lithodomus*), which attacked it at a time when, owing to the subsidence of the land, the temple had been submerged more than 20 ft. beneath the sea. The floor of the temple was originally 15 ft. above the level of the sea, and, since submergence, has again been raised to about its original level.

Between
Wall-cases
6 & 7.

Wall-case
6A and
adjoining
pillar.

Among the forces which produce perplexing and curious forms and markings in the rocks are those to which the general name of **concretionary action** is frequently applied. The term is a convenient one, since, as it implies nothing, it cannot well be incorrect. A beautiful example of it is furnished by the dendritic markings seen on many flat surfaces, and often resembling mosses or sea-weeds. The manner of their production is illustrated in some artificial preparations by Professor William Watson. The iron pyrites (sulphide of iron) so common in the Chalk constantly assumes shapes which may be mistaken for fossils, and the same substance often does replace the original constituents of shells and similar objects, which are then said to be pyritised. The passage of water through the rocks, often carrying minerals in solution, is a frequent cause of spotting and of banded structure. The banded flints, of which some fine specimens are exhibited, are exceedingly common examples of such a process.

Concretions are frequently formed round some organic nucleus, as a plant or a fish, in consequence of the chemical action produced by the decaying matter. Some of the larger concretions often become cracked, and the cracks again filled up by the infiltration of carbonate of lime or a similar substance, which forms numerous partitions or septa through the concretion, which is then known as a septarium. In addition to the examples of septaria shown in Wall-case 6, there is a polished section of a fine one from the Oxford Clay of Weymouth, fixed on the north wall of the Gallery. The curious forms assumed by flint in the Chalk should by this time be well known, and yet there are many people who still offer curiously shaped flints to the British Museum under the impression that they are rare fossils. A few specimens obtained in this way are here shown as a warning to others. It will, however, be noticed that many flints do actually contain fossil animals. Among the extraordinary forms assumed by flints, particular mention may be made of the pot-stones or Paramoudras, common in Norfolk. These huge, roughly cylindrical masses, usually with a central cavity, are arranged in vertical columns in the Chalk, and often pass through it for long distances. Specimens and illustrations of these are exhibited.

We come next to a fine series of concretions collected, chiefly by Mr. G. Abbott, from the Magnesian Limestone of Upper Permian Age at Fulwell Hill and Marsden in Durham.

Gallery XI.

Wall-case
6B.Wall-case
6c.Between
Wall-cases
1 & 2.Wall-case
7A, 7B.

Gallery XI. Several of these have a curious structure which produces in them a close resemblance to the skeletons of corals. Some larger masses of rock exhibiting the same structure are in the N.E. corner of the Gallery.

Further examples of concretions and other markings produced in various ways, not themselves organic, but curiously **simulating organic objects**, such as a human skull, the tooth of an elephant, a dog's head, plants, and fruits, are exhibited in order to impress upon beginners in the study of fossils the truth that here, if anywhere, things are not always what they seem.

The term "fossils," as has already been said, is applied not only to the remains of animals and plants, but to various traces left by them. The footprints of many animals with which we are more or less familiar are easily recognised, and many such, exhibited in Wall-cases 8, 9, and 10 on the east wall, are described in the Guide to the Fossil Reptiles. The more lowly animals, however, produce tracks which are less well known, and while certain markings found in the rocks can reasonably be explained by reference to the tracks and imprints of animals or plants now living, others still lack a convincing explanation. Here may be seen **tracks** ascribed to marine worms, crustaceans, and jelly-fishes; others, which have been ascribed to fossil plants and have received learned names accordingly, are now supposed to be either the tracks of some animal, such as a worm, or even the markings left by currents or eddies in the water. **Markings** obviously ascribable to such inorganic agencies—for example, ripple marks and the prints of rain drops—have been found in rocks of all ages, appearing just like the "ribbed sea sand" of to-day, or the rain prints newly formed on any wet surface of mud or sand, such as the stretches left when the tide goes out at the Bay of Fundy.

PROTOZOA.

Gallery X. Entering Gallery X, either from that last described or from the Gallery of Fossil Reptiles, No. IV, we pass down its left or western side to the far end. Here are exhibited the remains of the lowest forms of animal life that are preserved as fossils. These are the Foraminifera and the Radiolaria, two sections of the Phylum or great group Protozoa (first, i.e. simplest, animals).

The Protozoa are animals of simple structure and usually of minute size. In them the soft substance of the body is not divided into cells, such as build up the body-tissues of all other animals, and consequently they have no definite tissues. They have been called unicellular animals, but a single Protozoon often comprises more than is to be found in any one cell of a multicellular animal. In the latter each cell is trained for some special service and has dropped the qualities not essential to that service, whereas the body of the Protozoon has to fulfil all functions of the animal economy. Microscopic investigation, moreover, has shown that the minute drop of viscous protoplasm which constitutes the body of even the simplest Protozoon has really a most complicated structure. By keeping this in mind we shall better appreciate the significance of those exquisite skeletons formed by the Foraminifera and Radiolaria and frequently preserved as fossils.

A fuller account of living Protozoa is given in the *Guide to the Coral Gallery* in the Department of Zoology. It is there explained how in some Protozoa the outer surface of the body is hardened, so that the animal retains always a definite shape, and can usually take in food only at one permanent opening. Further, the surface is generally provided with definite lash-like or hair-like processes capable of rapid rhythmic movement. Those Protozoa are called **Corticata**, and since they have no skeleton to be fossilised, need no further mention here. The rest of the Protozoa have no hard skin, so that either the whole body may change its form within certain limits, or portions of its protoplasm may be extended as lobes or threads and again withdrawn. By stretching out a lobe, and then as it were flowing into it, the animal moves, and therefore these extensions are called pseudopodia (false footlets). Fragments of food are caught up in them and taken into the central body at any point. These Protozoa are called **Gymnomyxa** (naked slimes) or **Rhizopoda** (root-feet). They may be divided into the Classes: I. **Lobosa**, with lobose pseudopodia, e.g. *Amoeba*. II. **Heliozoa** or Sun Animalcules, with fine radiating pseudopodia. III. **Foraminifera**, with pseudopodia branching and again uniting so as to form a network. IV. **Radiolaria**, with fine radiating pseudopodia, as in Heliozoa, but with the central protoplasm enclosed in a porous membrane or capsule. In each of these groups there are some genera that construct a skeleton and others that do not; but in the

Gallery X. Lobosa and Heliozoa skeleton-builders are few, and their remains have not been found in any rock. In the Radiolaria, on the other hand, the large majority form a skeleton, while in the Foraminifera there are very few without it well developed. These two groups, therefore, are abundantly represented in the fossil state.

CLASS FORAMINIFERA.

Table-case 16. The skeleton deposited by the protoplasm of these animals generally consists of carbonate of lime, and is called the shell
Wall-case 9.

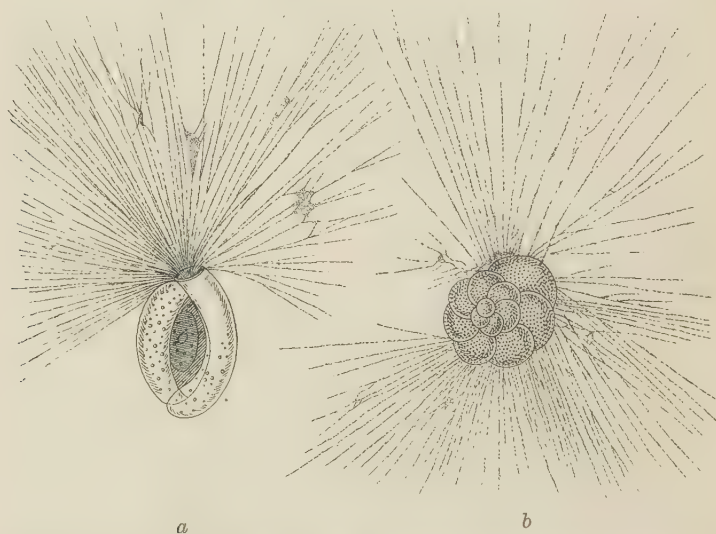


FIG. 1.—Living Foraminifera, with extended pseudopodia, some of which may be supposed to stretch far beyond the limits of the page. *a* is an Imperforate Foraminifer, *Miliola tenera*, the nucleus (darkly shaded) and the surrounding protoplasm, with its bubbles, prevent the inner chambers from being seen. *b* is a Perforate Foraminifer, *Rotalia veneta*, and shows the pores through which the pseudopodia stretch on all sides. Both enlarged 36 diameters. (Modified from M. S. Schultze, 1854.)

or test. Sometimes, especially in fresh-water species, it consists of chitin, a horny substance, and is not found fossil. In several a chitinous or thin calcareous coat is strengthened by grains of sand or other foreign particles, as is the case of a caddis-worm, and some tests of this arenaceous composition

are preserved in the rocks. This shell encloses the main mass of protoplasm, but the pseudopodia stretch out through certain openings. Either they are confined to the aperture of the shell, or the whole shell-wall is pierced by minute tubes through which the protoplasm can pass (Fig. 1). Shells of the first kind are called Imperforate, and may be chitinous, arenaceous, or calcareous. Shells of the second kind are called Perforate, and are generally calcareous. The Imperforate calcareous shells are chalky-white and rather like porcelain in appearance, whence they are called Porcellanous. The Perforate calcareous shells are of more glassy appearance, and are therefore called Hyaline. Both types of calcareous shell are made of calcite, but in porcellanous shells this is less pure. Attempts to classify Foraminifera according to the composition of the shell have not proved satisfactory, since genera or species which in other respects appear closely allied differ in this respect.

The form of the shell varies greatly. It may be simply flask-shaped, without divisions, e.g. *Lagena* (Fig. 3 *f*); or the animal may grow out of the opening of such a single chamber and fashion for itself another chamber adjoining the first, and as it grows it may build chamber after chamber (Fig. 2 *a*). Shells of the former type have been called

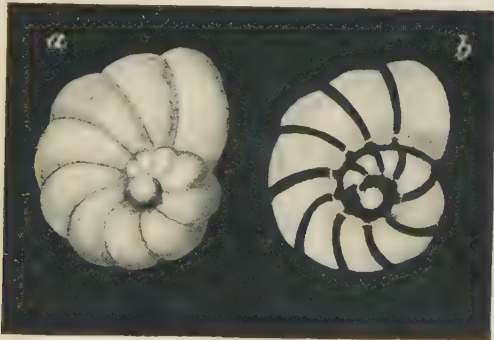


FIG. 2.—A Foraminifer from the Upper Chalk, *Anomalina ammonoides*. *a*, the shell; *b*, flint cast of the chambers of a similar shell, showing the form of the protoplasmic body. Highly magnified. (From Chapman's "Foraminifera," after Eley. By permission of Messrs. Longmans.)

Monothalamia (single-chambered), those of the latter type, Polythalamia (many-chambered). A hundred years ago,

Gallery X.

many of the Polythalamia were supposed to belong to the Cephalopoda, that Class of Mollusca which contains the nautilus and ammonite with coiled and chambered shells so like those of some Foraminifera, but on an enormously larger scale (see p. 151, Fig. 82). A. D. d'Orbigny, however, whose attention had been directed to the shells found by his father in the sea-sand near Rochelle, and who had studied similar sands and fossiliferous deposits from various parts of the world, published a memoir in 1826, pointing out that these microscopic forms differed from the true Cephalopoda in having no tube or siphuncle passing through the chambers, but simply one or many holes or foramina through the walls or septa that separate one chamber from the next; he therefore distinguished them as "Foraminifères" (hole-bearers). By observation of the living animal, Dujardin in 1835 discovered the more essential difference that, whereas the body of a nautilus is an elaborate structure confined to the last-formed chamber of the shell, the body of a chambered Foraminifer fills every chamber and is of simple protoplasm, connected throughout. Thus the flinty casts of the chambers of some Foraminifera found in the flint-meal of Chalk flints represent the form of the original animal, without the pseudopodia (Fig. 2 *b*).

Table-case
16.

The diversity of form assumed by the shell may be studied in the two series of plaster models shown on the top shelf of the Wall-case. One of these series was made by A. D. d'Orbigny and issued to his subscribers, about 1825, in four "Livraisons" or sets of twenty-five each. The label sent therewith described them as "Models of microscopic cephalopods, recent and fossil, representing one example from each of the chief divisions of a new classification based on the mode of growth of the shell. The diameter of these models is from 40 to 200 times that of the original shells. . . . The coloured models represent the fossil shells; the white models, the recent shells. The position and shape of the siphuncles [the openings between the chambers] are indicated by the marks or black spots." The models are labelled with the names originally attached to them by d'Orbigny, and are arranged in the numerical order in which he sent them out. Unfortunately that order was one of pure convenience and did not correspond with his classification; it is, however, the order followed in a subsequent description of the models and revision of their names by W. K. Parker, T. Rupert Jones, and H. B. Brady (Annals and Mag. Nat. Hist., July, 1865).

Wall-case
9B.

Many species marked by d'Orbigny as fossil are now known to live also in modern seas, and many recent ones have since been found fossil. In the following classification these models are referred to as "O 1, 2, 3, &c."

Gallery X.

The adjoining series of models, prepared by Prof. A. E. Reuss and Dr. Anton Fritsch of Prague in 1861, was intended to supplement the series by d'Orbigny. These are arranged in the order of the catalogue issued with them, the classification being that of Reuss. Since an account of it is given in the paper by Parker, Jones, and Brady, quoted above, we need say here only that Nos. 1-30 are Imperforata; Nos. 31-100, Perforata; Nos. 1-18 have arenaceous shells, while all the rest are calcareous. These models are referred to as "R 1, 2, 3, &c."

Wall-case
9B.

The classification followed in the arrangement of the actual specimens, whether British or foreign, is that used by Brady in his report on the Foraminifera collected by H.M.S. 'Challenger.' According to this, the genera are arranged in ten families, nowadays often raised to the rank of Orders. These are: (1) **Allogromiidae**, horny-shelled and mostly freshwater; none fossil. (2) **Miliolidae** (Fig. 3, *a, b, c*), comprise all porcellanous shells; this division exhibits a great many plans of shell-building, including several that are also found among arenaceous and hyaline Foraminifera; examples of nearly all these occur as fossils. (Models, O 8, 18, 31-33, 90-97, 100, R 16-21, are Miliolinae; O 22, 81, R 26, 27, are Hauerininae; O 16, 20, 21, 24, 48, R 15, 22-25, 29, 30, are Peneroplidinae; O 50, Alveolininae). (3) **Astrorhizidae**, arenaceous and irregular, usually single-chambered and seldom truly septate; *Saccamina* is well known in Carboniferous Limestone, but there are few other fossils of this family. (4) **Lituolidae** (Fig. 3, *d, e*), arenaceous, truly septate and more regular; the shell-form is diverse; and among exhibited fossil examples of the various types are *Lituola* (R 1-4, 13), *Trochamina*, *Nodosinella*, *Stacheia*, and *Endothyra*. Except for a few Endothyrinae, all the preceding families have essentially imperforate shells; the remaining families are essentially Perforata. (5) **Textulariidae**, usually arenaceous, but the smaller species are hyaline; shells usually composed of a double or triple series of alternating segments; *Textularia* (Fig. 3, *l*, O 7, 28, R 75) is a common fossil (O 2, 25, 56-58, 66, R 5-7, 10-12, 14, 28, 76, belong to the same sub-family); *Bulimina* (Fig. 3, *n*, O 9, 68, R 8, 9, 64, 85),

Gallery X.
Wall-case
9.
Table-case
16.

Virgulina (O 64, R 58, 65), and *Bolivina* (R 79) are exhibited fossil representatives of Bulimininae; *Cassidulina* (Fig. 3, *m*, O 41, R 81, 82) is the type of a third sub-family. (6) **Cheilostomellidae**, calcareous, thin, and finely perforate, with successive chambers in single, alternate, or triple series. *Allomorphina* (R 74), *Cheilostomella* (R 73), and *Ellipsoidina* are Cretaceous or Tertiary fossils. (7) **Lagenidae** (Fig. 3, *f-j*), hyaline and finely perforate, simple shell-wall; starting with a flask-shaped or spheroidal chamber as in *Lagena* (R 33-35), other types are formed by the addition of chambers in straight series, e.g. *Nodosaria* (O 1, R 36-38), or curved e.g. *Marginulina* (O 6, 55, R 55, 57, 59, 60, 72), or spiral, e.g. *Cristellaria* (O 14, 19, 44, 47, 82-85, R 61-63), or in alternating double or triple series, e.g. *Polymorphina* (O 23, 29, 30, 61-63, R 67-70), while in *Ramulina* the chambers are joined by branching tubes; all the genera mentioned are widely distributed as fossils; (others are O 3, 4, 26, 27, 51-54, 60, 67, R 40-54, 56, 66, 77). (8) **Globigerinidae**, hyaline shell of a few swollen chambers spirally arranged, *Globigerina* (Fig. 3 *k*, O 17, 76, R 91; others are O 43, 65, R 71, 92, 95). (9) **Rotaliidae** (Fig. 3, *o, p*), hyaline shell typically composed of chambers wound spirally like a snail-shell, and either free or attached; (*Spirillina*, R 31; Rotaliinae, O 10, 12, 13, 15, 34-39, 42, 49, 69-75, 77-79, 89, R 83, 84, 86-90). (10) **Nummulitidae** (Fig. 3, *r-t*), shell consists of a series of chambers coiled in one plane, and is often thickened by extra layers of shell-substance connected with a system of canals distinct from the ordinary communications between the chambers and the perforations of the shell-wall; among important fossils are *Fusulina* (R 96), *Nonionina* (O 11, 46, 86, R 94, 96), *Polystomella* (O 45, R 93), *Amphistegina* (O 40, 98, R 97), *Operculina* (O 80, 88, R 98), *Heterostegina* (O 99, R 99, 100), *Nummulites* (O 87), and *Orbitoides*. The complication of structure sometimes attained in this family may be studied in an enlarged model of a *Nummulite*.

Table-case
16.

ROTAIIDAE—*o*, *Rotalia*, Lower Cretaceous to Recent; *p*, *Truncatolina*, Carboniferous to Recent.

NUMMULITIDAE—*r*, *Archæodiscus*, Carboniferous; *s*, *Polystomella*, Jurassic to Recent; *t*, *Amphistegina*, Carboniferous, and Tertiary to Recent.

The Epoch mentioned after each genus is the oldest in which it is found; all, except *Archæodiscus*, survive to the present. The figures are variously enlarged, from 10 to 100 diameters. (From Nicholson's "Palæontology," after H. B. Brady.)



FIG. 3.—Examples of Foraminifera:—

MILIOLIDAE—*a*, *Cornuspira*; *b*, *Quinqueloculina*; *c*, *Peneroplis*: all Tertiary to Recent.

LITUOLIDAE—*d*, *Lituola*, Carboniferous to Recent; *e*, *Trochammina*, Lower Lias to Recent.

LAGENIDAE—*f*, *Lagena*; *g*, *Nodosaria*; *h*, *Marginulina*: all Cambrian to Recent; *i*, *Frondicularia*, Permian to Recent; *j*, *Polymorphina*, Trias to Recent.

GLOBIGERINIDAE—*k*, *Globigerina*, Cambrian to Recent.

TEXTULARIIDAE—*l*, *Textularia*, Cambrian to Recent; *m*, *Cassidulina*, Lower Cretaceous to Recent; *n*, *Bulimina*, Jurassic to Recent.

Gallery X.

The marine Foraminifera, with which geologists are chiefly concerned, are found on sea-weed and similar objects on the sea-floor, from shore pools down to great depths, and from arctic to tropical waters, sometimes fixed and sometimes free; they live chiefly on diatoms and algae. Most of the Globigerinidae float in the warm surface-water of the great oceans down to a depth of 500 fathoms, and stretch out their pseudopodia along delicate spines; these eat also minute animals.

The empty shells are found in all kinds of marine deposits. Numbers are drifted ashore, as at Rochelle and at Dog's Bay, Connemara, whence 124 kinds have been

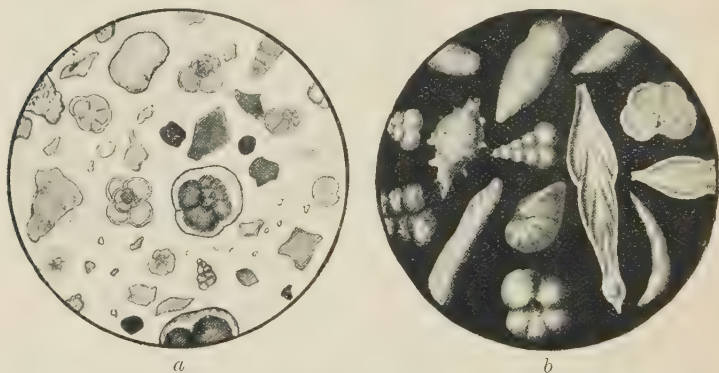


FIG. 4.—Foraminifera as Rock-formers. *a*, Globigerina Ooze, from a depth of 2,760 fathoms in the North Atlantic. $\times 24$ diameters. *b*, Foraminifera washed from Chalk rock near Dunstable. $\times 36$ diameters. (From Chapman's "Foraminifera." By permission of Messrs. Longmans.)

obtained. An ounce of sand from the Adriatic yielded 6,000 shells. Deposits dredged from the sea-bottom contain each a special assemblage varying with the nature of the bottom, depth, and temperature. Such are the coral sands of the Pacific, and the greensands formed at about 500 fathoms. In the latter the empty shells become filled with a green siliceous mineral (glauconite) and often disappear, leaving their casts behind. In the deeper parts of the ocean, especially where the surface is warm, is found an ooze mainly consisting of the shells of Globigerinidae and other pelagic forms (Fig. 4 *a*); its extent is estimated at 49 millin square miles, and its thickness must be enormous.

It is natural, therefore, that Foraminifera should not

merely be common fossils, but that they should have helped to build up large masses of rock. From Cambrian to Devonian times they are rare, and no specimens of those periods are exhibited. Among the Carboniferous specimens may be seen limestones composed of the Astrorhizid genus *Saccamina* from Britain, of the Lituolid *Endothyra* from Indiana, and the Nummulitid *Fusulina* from Russia; also isolated shells of *Archæodiscus*, a primitive Nummulitid, of the Lagenids *Dentalina* and *Nodosaria*, and of *Textularia*. The last two genera also occur among the foreign Permian specimens, and *Trochamina*, a Lituolid, among those from Britain.

The Jurassic marls and shales contain immense numbers, mostly of the small perforate and arenaceous forms not easily placed on exhibition. Among the British specimens from the Oxford clay is an oyster-shell covered with the irregular adherent Lituolid, *Webbina*. The Cretaceous system furnishes greensands, in which, as above explained, the actual shells are rarely preserved; but some fragments with the large Rotaliid *Patellina* are shown in both the British and foreign series. Its characteristic rock, however, is the white Chalk, which in some parts approaches a *Globigerina* ooze, and contains numerous shells of *Globigerina*, *Cristellaria*, *Nodosaria*, *Textularia*, *Lituola*, and other genera (Fig. 4 b). These may be preserved in flint, and many such figured in the Rev. H. Eley's "Geology in the Garden" (1859) are in the British Case. From the Maestrichtian Chalk are shown the flat circular *Orbitoides* and the spurred *Calcarina*.

As examples of Eocene limestones, mainly formed by Foraminifera, may be noted the Paris building-stone with *Miliola*, an *Alveolina* limestone from Persia and from Selsea, a French rock with *Orbitolites*, and another with *Orbitoides* from both Biarritz and India. During the same period were formed the various Nummulitic limestones, of which numerous examples are shown from countries round the Mediterranean, also from S.E. Africa and India, while in the British series are specimens of the slighter development at Alum Bay and Bracklesham. Here also are many smaller forms obtained by washing the London Clay, and others of Pliocene Age from the Coralline Crag of Suffolk.

The **Nummulites** have attracted the attention of learned writers from Strabo downwards, but have recently acquired fresh interest owing to a curious problem connected with the

Gallery X.

Table-case
16.

Wall-case
9b.

Table-case
16.

Wall-case
9.

Table-case
16.

Gallery X.
Table-case
16.

reproduction of the Foraminifera. Examination of some of the pieces of nummulitic limestone will show that nummulites of two sizes are usually associated in the same rock. These were formerly supposed to be distinct species, and so received distinct names. On splitting the shell of a nummulite it is found that the spiral series of chambers starts from a central spherical chamber, and in these paired forms it has been observed that in the larger shell the central sphere is of microscopic size, whereas in the smaller shell it is readily visible to the naked eye (Fig. 5). In

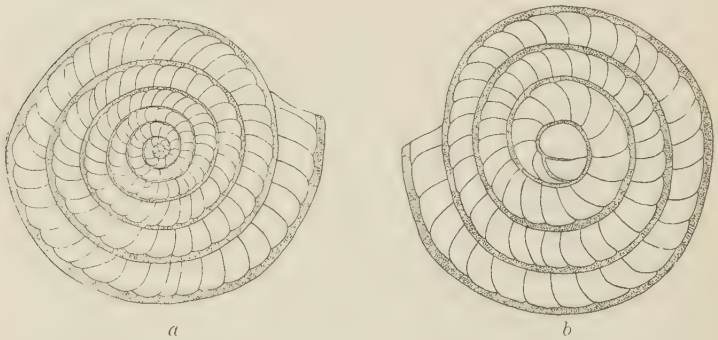


FIG. 5.—Two generations of a Nummulite. Sections across (a) *Nummulites laevigatus*, showing the small central chamber, and (b) its other form known as *Nummulites Lamarcki*, showing the large central chamber. Both from the Eocene of Stubbington; enlarged 10 diameters. (Copied from the original figures by De la Harpe, 1881.)

consequence of their universal association it was inferred that the large circles with small spheres and the small circles with large spheres were really two forms of the same species; and it was then found that similar dimorphism, i.e., composition of a single species by two forms, occurred in the shells of many other genera of Foraminifera. By observation of living individuals of one of these (*Polystomella*), Schaudinn and Lister have proved that the dimorphism results from the alternation of two modes of reproduction: the small-sphered form extrudes from the shell the whole of its protoplasm, which then separates into spheres, and round each of these is deposited a shell which proves to be the central chamber of a large-sphered form. In such a form the protoplasm ultimately divides into a multitude of minute two-tailed particles or spores, which are ejected. When a spore from one individual meets a spore from another it

fuses with it, and round the united pair grows a shell which proves to be the central chamber of a small-sphered form. Gallery X.

The two forms of shell are to be seen in the following two pairs of so-called species; in each case the name which has to be adopted for the whole species, and under which it is exhibited, is the one printed in italics. Table-case 16.

LARGE CIRCLE, SMALL SPHERE.	SMALL CIRCLE, LARGE SPHERE.	FORMATION AND COUNTRY.
<i>Nummulites complanatus</i> , Lamarck.	N. Tchihatcheffi, d'Archiac.	Eocene and (?) Miocene, France, Bavaria, Hungary, Egypt, India.
<i>N. perforatus</i> (de Montfort).	N. Lucasanus (De-france).	Eocene, India.
<i>N. gizehensis</i> (Forskål).	N. curvispirus (Savi and Meneghini).	Eocene, Egypt.
<i>N. laevigatus</i> , Lamarck.	N. Lamarcki, d'Archiac and Haime.	Eocene, France, England (Bracklesham).
<i>Assilina exponens</i> (Sowerby).	<i>Assilina mammillata</i> (d'Archiac).	Eocene, India, Bavaria.

A "Catalogue of the Fossil Foraminifera in the British Museum," by T. R. Jones, was published by the Trustees in 1882. See further Carpenter, Parker, and Jones "Introduction to the study of the Foraminifera," London, Ray Society, 1862; Chapman "The Foraminifera," London, 1902; Lister, Section on Foraminifera in Lankester's "Treatise on Zoology," London, 1903, and Address to Section D, British Association, 1906.

Eozoon.

This green serpentinous rock, in wavy layers, which was formerly thought, chiefly by W. B. Carpenter and J. W. Dawson, to have been built up by a colonial Foraminifer, called by them *Eozoon* (the dawn animal), is found in some of the very oldest rocks in Canada and Bohemia. A similar mineral structure, however, also occurs in much later rocks, including some of undoubted igneous origin. The organic nature of *Eozoon* is therefore upheld no longer, but the hypothesis had its uses in the impetus which it gave to the microscopic and chemical study of rocks. Wall-case 9B, corner.

CLASS RADIOLARIA.

Gallery X. The central mass of protoplasm with the nucleus is surrounded by a horny membrane, forming a capsule. This, in its simplest form, is spherical, and scattered evenly over its surface are numerous pores through which the protoplasm within it communicates with that outside it. In a higher stage the pores are grouped into several areas but these in their turn are evenly distributed, so that there is still no definite axis. All these constitute the Porulosa of Haeckel.

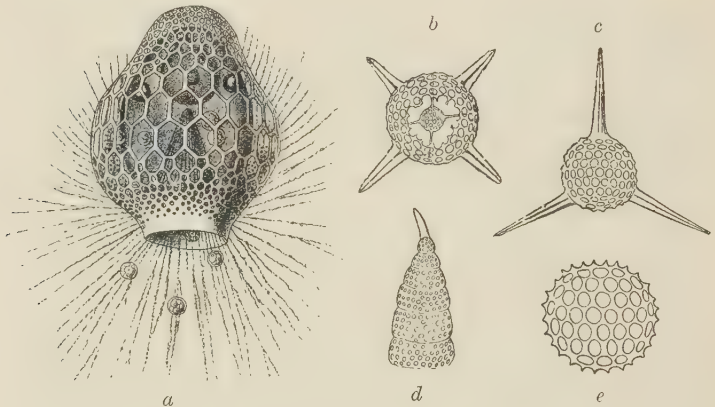


FIG. 6.—Radiolaria, Recent and Fossil. *a*, a living Radiolarian of the Order Nassellaria, *Cyrtocalypis urceolus*. Within the siliceous test is seen the central capsule, from the lower part of which the pseudopodia stream out through the mouth and lower meshes of the test. In the upper half is the large nucleus, on each side of which is an oil globule. The lighter round bodies are yellow algæ. Enlarged 200 diameters. (After Haeckel, 1887.) *b-e* are fossil Radiolaria, *b*, *c*, and *d* being of Carboniferous age, and *e* being Silurian. *b* and *e* are examples of Spumellaria Sphaeroidea; *c* of Spumellaria Discoidea; and *d* of Nassellaria Cyrtioidea. All greatly magnified. (After Rüst.)

In the other Radiolaria, which Haeckel names *Osculosa*, the pores are concentrated in a basal region called the osculum; thus the capsule has a central axis with a basal and an apical pole; smaller oscula may occur near the latter. In each of these divisions a skeleton may be developed, either of pure silica or of other substance.

On these bases the Radiolaria are divided by Haeckel into four Orders: 1. **Spumellaria**: Porulosa, with pores scattered; skeleton of solid silica. 2. **Acantharia**: Poru-

losa, with pores grouped; skeleton of strontium sulphate. **Gallery X.**
 3. **Nassellaria**: Osculosa, with one basal osculum; skeleton, when present, of solid silica. 4. **Phaeodaria**: Osculosa, with the capsular wall projecting around the basal osculum as a tube; two or more smaller oscula may be at the apical pole, extracapsular protoplasm contains dark pigment granules (phaeodium); skeleton of silica combined with organic matter.

Only the glassy skeletons of pure silica—as occurring in **Table-case 15.** Orders 1 and 3—are found fossil. These skeletons, though manifesting extreme diversity of shape, conform in general plan to the structure of the central capsule, as may be seen from the greatly enlarged models in Table-case 15. Thus in Spumellaria the skeleton is usually a sphere of lattice-work (Fig. 6 *e*), or several such spheres one within the other (Fig. 6 *b*), and joined by cross-bars which radiate from the innermost sphere but do not meet at the centre, and which project as spines (Fig. 6 *b* and *c*). The sphere may be pulled out to an ellipsoid, or compressed to a discoid. In Nassellaria the skeleton is generally in the shape of a bell or of an elongated cone, which may be transversely constricted at intervals (as in Fig. 6 *d*); there may be a spine at the apex and others projecting from the basal margin. All these skeletons are so minute that their form can scarcely be distinguished by the naked eye.

Radiolaria live only in the sea, where they float in all parts and at all depths, but mainly near the surface of tropical oceans. On death their skeletons sink to the bottom, but those not made of pure silica are dissolved by the seawater; and where the ocean is very deep the calcareous shells of the Foraminifera are also dissolved as they sink. Hence at depths of from two to four miles the ooze of the ocean-floor is formed almost entirely of the siliceous skeletons of Radiolaria. Similar radiolarian ooze has been deposited in past geological epochs, and when found among the rocks bears witness as a rule to an upheaval of that part of the earth's crust from a great depth. In the rocks of Tertiary age, such dried oozes are known as Tripoli stone (*Kieselguhr*), and occur in many parts of the world. The Radiolaria from several of them were described by Ehrenberg (1838-1873) under the name Polycistines. On the bottom shelf of **Wall-case 9B.** in the corner, is a large core of the Miocene radiolarian marl of Barbados, from which 400 species have been described; and a glass slide with

Gallery X.
Table-case
15.

Radiolaria from a similar rock in Cuba, with illustrative drawings, is shown in Table-case 15. In these soft Cainozoic deposits many Radiolaria belong to species still living, and their skeletons are as perfect as those in modern ooze. In the Mesozoic and Palaeozoic rocks, however, the oozes have been changed, by pressure, or heat, or the percolation of water, into quartzites, cherts, and flinty shales, so different in appearance that their radiolarian origin has not long been

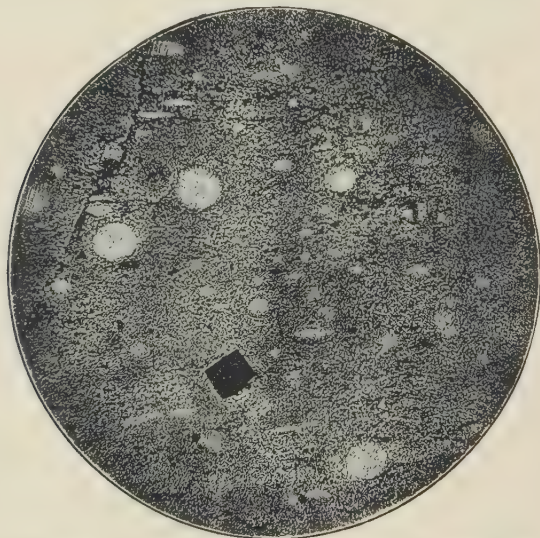


FIG. 7.—Radiolarian rock from the Lower Culm at Carzantic Quarry, near Launceston, Cornwall. Appearance of a thin section as seen under the microscope. Enlarged about 32 diameters. (From paper by Hinde and Fox in the "Quarterly Journal of the Geological Society," vol. li; by permission of the Council.) (See Table-case 15.)

discovered. This was done by examining thin sections of the rock under the microscope, when in some, less altered than most, the skeletons were recognised. Usually, however, the skeletons themselves have been dissolved, and there can only be detected spots of transparent silica formerly deposited in the cavity of the skeleton. In this way Radiolaria have been found in siliceous rocks as far back as to the Cambrian period. In illustration of this are exhibited specimens of the radiolarian chert and shale of Carboniferous age, found in the Lower Culm of Devonshire and Cornwall (Fig. 7), and Ordovician cherts from Cornwall and the south of Scotland.

Table-case
15.

Drawings of the species found in these rocks by Dr. G. J. Hinde are exhibited alongside. Other specimens of Radiolarian rock from foreign localities are also shown. Radiolaria are occasionally found scattered through rocks other than cherts, but as a rule their delicate skeletons have been dissolved away.

Gallery X.
Wall-case
9.

See further Haeckel's "Report on the Radiolaria collected by H.M.S. 'Challenger,'" 1887, in which the fossil species are also dealt with.

PORIFERA (SPONGES).

Next the Protozoa come the fossil remains of sponges, the foreign ones being displayed in the Wall-cases, and the British ones in the Table-cases. Among the latter will be seen many of those preserved in flint, and familiar either to collectors in the chalk-pits or the searchers for pebbles on the beach. To explain the structure of these a rather long description is necessary.

Wall-cases
7, 8.
Table-cases
11-15.

Sponges are animals most of which live in the sea at all depths, while one family alone is found in fresh water. Since they have no organs for locomotion, sense, or reproduction, they are usually indefinite in shape as well as very variable in size. The only organs readily seen are several holes, often mounted on slight projections at various parts of the surface; from these holes, which are called "oscula," a current of water is always issuing. Closer examination discovers scattered over the whole surface a far larger number of small openings through which the water is as constantly being drawn in; these are called "ostia." Study of thin sections of a sponge under a microscope shows how this flow of water through the sponge is brought about. The water that enters the ostia is led by irregular winding canals into the deeper parts of the sponge. These incurrent canals open by very minute pores into a number of small round chambers, whose walls are furnished with little lashes (or "flagella") in constant motion. From each such flagellated chamber the lashes are continually driving the water through a wide opening into another set of canals, the excurrent canals, which lead it out to the oscula. The sponge, unlike the animals hitherto considered, is a combination of many cells, modified for various services. Thus the outer surface and the walls of the canals are coated with flattened cells; the cells lining the flagellated chambers bear each a lash surrounded by a collar

Gallery X. (collar-cells), so that they closely resemble certain Protozoa; interspersed among these are other cells, each of which is pierced by one of the very minute pores mentioned above; the substance surrounding the chambers is a jelly containing various cells, among them the germ-cells and the spicule-cells. For further information as to the soft parts, recourse should be had to the exhibit in the Zoological Department.

All this soft mass of the sponge is supported by a skeleton built up from the tiny spikes or rods deposited by the spicule-cells. In the common bath-sponge, as in many modern sponges, the substance of the skeleton is horny, and appears incapable of preservation in the fossil state. In

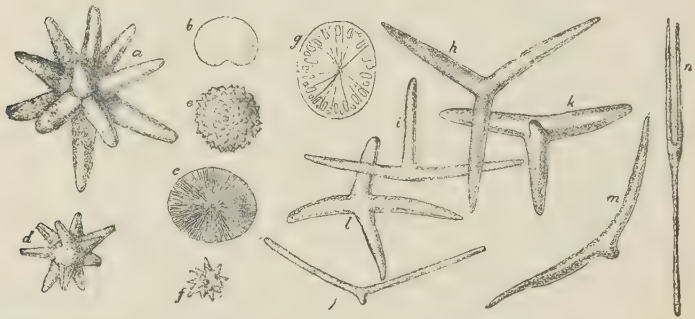


FIG. 8.—Fossil sponge spicules: Silicispongiae, Heteractinellida, skeletal spicule (*a*); Silicispongiae, Tetractinellida and others, flesh spicules (*b-g*); Calcispongiae, skeletal spicules (*h-n*). *a* is from *Asteractinella*; *b, c* from *Geodia*; *j-l* from *Tremacystia*. *a* is enlarged 13 diam.; *b-g*, 66 diam.; *h*, 26 diam. *i*, 114 diam.; *j, m, n*, 134 diam.; *k, l*, 80 diam. (After Hinde.)

other sponges the skeleton is either calcareous, i.e. composed of carbonate of lime (calcite), or siliceous, i.e. composed of flinty spicules. Each of these latter is further distinguished by being deposited around an axial filament of softer tissue, which disappears in the fossils, leaving an axial canal. The siliceous sponges constitute the larger and more important group, and are the better preserved as fossils; in some of them the siliceous skeleton partly gives place to horny fibres, a change which suggests how the true horny sponges arose.

The spicules, whether of calcite or of silica, are built on certain plans which are utilised in classification. The main types are: (1) Monaxons (Fig. 14), spicules of rod-like form, that grow out from a single point of origin either

in one direction (one-rayed) or in two directions (two-rayed), but in the latter case the two rays lie along a single axis; the axis is straight or curved. (2) Triaxons (Fig. 9), spicules that grow out from a single origin in both directions along three axes at right angles to one another, thus producing six rays, some of which may, however, be suppressed. (3) Tetraxons (Fig. 11), spicules that grow out in one direction only along four axes which meet at equal angles; thus there are four rays, one or more of which may be suppressed. In the latter case tetraxon rays may be distinguished from those of triaxons by meeting at an angle of about 120° instead of 90° or 180° . (4) Polyaxons (Fig. 8, *a, d*), which grow out along several axes radiating from a common centre. The modifications and associations of these four types can be gathered from the accompanying figures. These types are more conspicuous in the larger spicules that build the skeleton; there are also smaller flesh spicules or skin spicules of more irregular shape (Fig. 8, *b-g*).

Gallery X.

Frequently sponges are divided into only two Classes:— (I.) Those with spicules of calcite, called **Calcispongiae** or Calcarea; (II.) all the rest, called **Silicispongiae** or Silicea. There is however considerable difference between those Silicea having six-rayed spicules or triaxons, and all the others, so that the following classification has been proposed.

Branch: **CALCISPONGIAE.**

Class I.—**CALCAREA.**

Skeleton of calcareous spicules, either monaxon or tetraxon or both (Fig. 8, *h-n*).

Grade A.—**Homocoela.** Body a simple sac, which branches in the adult, but retains the simplest type of canal system, and is lined throughout by collar-cells. Although the most primitive forms, these have not yet been found fossil, probably because of their small size and imperfect skeleton.

Grade B.—**Heterocoela.** Canal-system broken up into separate flagellated chambers, to which the collar-cells are restricted. According to the degree of complexity of these chambers, and according to the shapes of the spicules, the Heterocoela are divided into six families, of which only one, the Pharetronidae, is largely represented in the fossil state. The Sycttidae, in which the chambers are radially arranged round the central cavity, are doubtfully represented

Wall-case
8B.

Gallery X. by the Jurassic *Protosycon*. The diminutive *Leucandra Walfordi* from the Middle Lias is the sole fossil example of the common recent family Grantidae, for in them the spicules are loosely and irregularly distributed chiefly around the chambers.

The Pharetronidae have a skeleton of fibres formed by spicules arranged side by side and interlocking, but not fused (except in the Lithoninae). In some a relatively large three-rayed or four-rayed spicule is enveloped by smaller thread-like spicules; in others the spicules are approximately equal throughout. In many there is an outer layer formed of a close felt of spicules. The more important genera are *Corynella* (Trias to Cretaceous), *Holcospongia* (Jurassic), *Elastomostoma* and *Peronidella* (Jurassic and Cretaceous), and *Pharetrospongia* (Cretaceous). All these belong to the Sub-family Dialytinae. The Lithoninae, in which the main spicules are fused, contain a few Tertiary and Cretaceous genera, of which the Chalk *Porosphaera* is the best known.

The structure of the skeleton has often been greatly altered in fossilization. The spicules have lost their outlines, and the fibres now appear as if entirely formed of granular or fibrous calcite. In other cases the fibres have been replaced by silica, so that they remain after treatment with acid, but all trace of spicules has been obliterated. In some specimens of *Pharetrospongia*, preserved in solid flint, the outer portion of the fibres has been replaced by silica, whilst their interior still retains the original calcite. The structure even in the best preserved specimens is hardly recognisable, unless in thin sections under the microscope.

The Calcarea of to-day are marine shallow-water forms; but some Pharetrones may have lived in deeper water.

Branch: SILICISPONGIAE.

Class II.—HEXACTINELLIDA.

Skeleton of siliceous spicules (Fig. 9), all triaxon and therefore primitively six-rayed (hexactine). Canal-system simple, with thimble-shaped chambers. The body-wall, which is relatively thin but may be thickened by folding, surrounds a wide funnel-shaped or cylindrical cavity (cloaca) into which the chambers discharge their currents (Fig. 10). In this wall the chambers are suspended by rafters (trabeculae) of soft tissue between an outer dermal membrane and an inner gastral membrane. The spicules are formed by cells

Table-cases
14, 12.

Wall-cases
8B, 7B, 7c.

Table-case
12.

Table-case
12.

in the trabeculae; some support the dermal membrane, some the gastral membrane, while others stretch across the body-wall between the two membranes; in *Lyssacina* yet other spicules project from the dermal membrane.

Modern Hexactinellids all live in the deep sea, fixed to the bottom or moored in the ooze by long tufts of rooting spicules. The best known is the beautiful Venus's Flower-basket (*Euplectella*).

SUB-CLASS I.—**LYSSACINA.** The spicules of the skeleton either remain separate or are united at a late period of growth in an irregular manner by siliceous masses or small transverse rods (synapticulae).

ORDER I.—**Hexasterophora.** In some of the spicules in the middle layers of the body-wall the rays branch, forming rosette-like bodies called hexasters. The chief

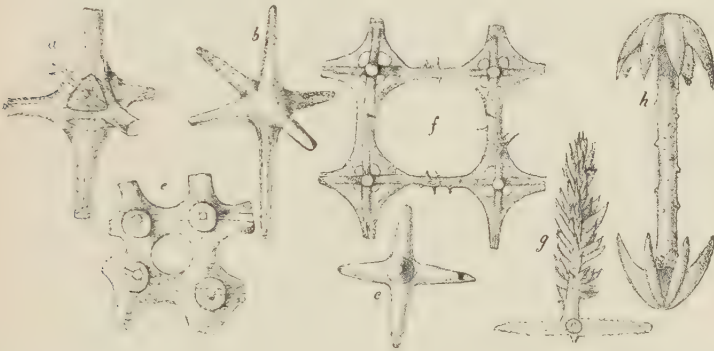


FIG. 9.—Fossil sponge spicules: Silicispongiae, Hexactinellida. *a-f* are skeletal spicules; *g, h* are flesh spicules. Six-rayed spicules are shown in *a, b, c, e, f*; in *c* one ray is suppressed. Axial canals are seen in *a, e* and *f*, and *a* and *f* have lantern nodes. *e* and *f* illustrate the union of spicules to form the square mesh of Dictyonina, *e* being from *Setrodictyon* and *f* from *Coeloptychium*; *g* is called a pinule, and *h* an amphidisc. *a* is enlarged 66 diam.; *b, c, f*, 40 diam.; *e*, 47 diam.; *g*, 134 diam.; *h*, 114 diam. (After Hinde.)

families are Euplectellidae, Asconematidae, and Rossellidae. Fossil representatives of the last two have been found in Eocene rocks.

ORDER II.—**Amphidiscophora.** There are no hexasters, but some spicules in the limiting membranes are in the form of rods with toothed disc-like expansions at their ends; they are called amphidiscs (Fig. 9 *h*). There is always an anchoring root-tuft. The living forms belong to the family

- Gallery X. Hyalonematidæ or Glass-rope Sponges, some of which are found fossil as far back as the Silurian. There are a number of extinct families: Protospongidæ (Cambrian and Silurian); Dictyospongidæ (Silurian and Devonian); Plectospongidæ (Ordovician and Silurian); Brachiospongidæ (Silurian); Pollakidæ (Carboniferous and Cretaceous), and others. Here also have been placed the peculiar **Receptaculitidæ** (Ordovician to Carboniferous), but it has been shown that their spicules were probably calcareous, and, although still
- Table-case 15.
Wall-case 8B, 8C.
- Table-case 12.
- Table-case 15.

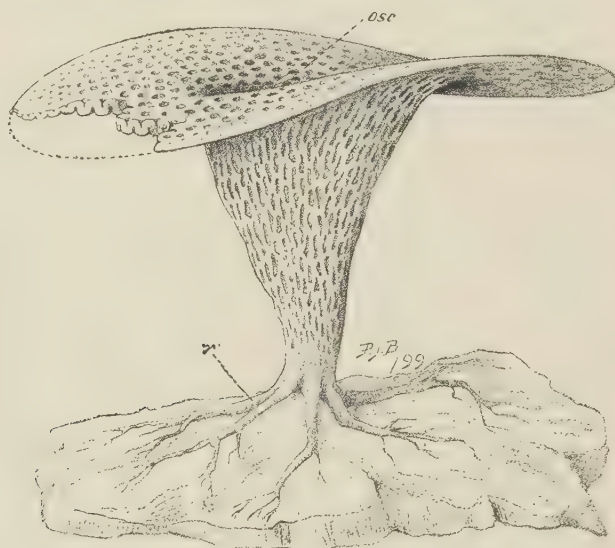


FIG. 10.—Reconstruction of *Ventriculites*, a Dictyonine Hexactinellid sponge from the English Chalk. *r*, root-like processes of attachment; *osc*, osculum leading from the cloaca. A piece of the margin is broken away to show the folds, which form the incurrent and excurrent canals. (After E. A. Minchin in E. Ray Lankester's "Treatise on Zoology." By permission of the Editor.)

exhibited near the sponges for the sake of convenience, they are now not considered to be sponges at all. Some suppose them to be calcareous algæ.

SUB-CLASS II.—**DICTYONINA**. The six-rayed spicules of the middle layers of the body-wall overlap by their ends and are then fused by a deposit of silica into a network, or rather rafterwork, with square meshes (Greek *dictyon*, a net).

Owing to their strong skeleton many Dictyonina are well preserved as fossils, representing the following families:—

Euretidae or Craticularidae (Jurassic to Recent): mostly cup-shaped or funnel-shaped; spicular nodes simple and imperforate; canal openings large, simple, ending blindly in the skeleton. Mellittonidae (Cretaceous, Eocene). Coscinoporidae (Cretaceous to Recent): in addition to the cup and funnel shape, many have thin walls folded into a series of flanges, e.g. in the Cretaceous *Guettardia*; surface canal-openings small, usually arranged in quincunx. Staurodermidæ (Jurassic and Cretaceous): usually funnel-shaped or cylindrical, with an irregular skeletal mesh and a definite dermal layer in which are large cross-shaped spicules. Callodictyonidae (Cretaceous). Ventriculitidae (Jurassic and Cretaceous): mostly funnel-shaped, with a thin wall thrown into vertical folds which are usually arranged radially (Fig. 10); spicular nodes hollow or lantern-shaped (Fig. 9 a); the base of the sponge has root-like extensions of spicular fibres. Coeloptychidae (Cretaceous): mushroom-shaped with a thin wall thrown into radial folds and enclosed in a perforate dermal layer; canal-openings in rows on the ridges of the under surface; lantern nodes. Mæandrospongidae (Cretaceous to Recent): pear-shaped, sack-shaped, or nodose masses, with a thin wall thrown into numerous folds, which join one another irregularly and are often partly or wholly enclosed by a fine spicular membrane, e.g. *Camerospongia*, *Cystospongia*, and *Plocoscyphia*.

Gallery X.
Table-cases
13, 12, 11.
Wall-cases
7, 8A.

Wall-case
7B.

CLASS III.—DEMOSPONGIAE.

Silicispongiae without triaxon spicules. These are the commonest sponges of the present day, most familiar in the freshwater sponge and the bath-sponge, but found in all waters in the most varied surroundings. Palaeontologists, however, are only concerned with those that retain siliceous spicules. According to the form of those spicules they may be divided, somewhat artificially, into two Sub-Classes.

SUB-CLASS I.—**TETRACTINELLIDA.** Demospongiae typically with tetraxon spicules (Fig. 11).

ORDER I.—**Choristida** (to which the term Tetractinellida is sometimes restricted). Spicules four-rayed and not joined into a rigid network. The simplest spicule has the form of a caltrop (Fig. 11 a, c). In others one ray is elongated, forming a shaft from which the other rays project as three prongs; this trident shape is called a triaene and is subject to much further modification (Fig. 11 f-k). With these

Gallery X. typical shapes other forms of spicule are associated (Fig. 8 *b-g*). The spicules are generally arranged in radial bundles, but since they are not fixed together, the skeleton has generally fallen to pieces in course of fossilization. Thus only a few forms have been preserved entire, e.g. *Pachastrella convoluta* from the Upper Chalk of Flamborough (Fig. 11 *a, l*). Detached spicules, on the other hand, are abundant, and form the main constituents of beds of sponge-rock in the Lower and Upper Greensand and in the Upper Chalk.

Table-case 11.

ORDER II.—Lithistida. Branching secondary spicules (desmas), which may or may not be modified tetraxons, interlock to form a rigid skeleton (Figs. 12, 13); triaenes also may be present (Fig. 13 *i*). Owing to the firm manner

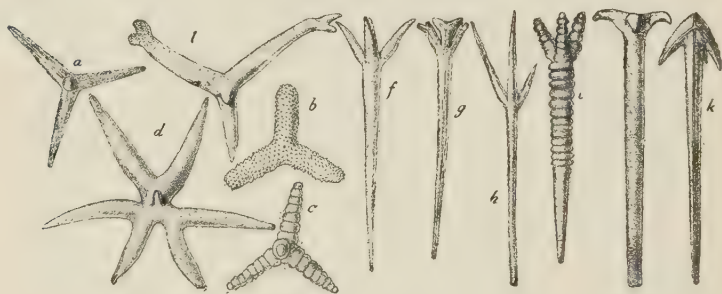


FIG. 11.—Fossil sponge spicules: Silicispongiae, Tetractinellida Choristida. *a* and *c* are regular four-rayed caltrops; *b* is a caltrop, with one ray suppressed; *l*, a caltrop with two rays branching. The rest are triaenes of various shapes, *d* being one in which the shaft is reduced and the head-rays forked and stretched out flat. *a* and *l* belong to *Pachastrella*. *a, g, j*, enlarged 26 diam.; *b*, 40 diam.; *c*, 54 diam.; *d, f, h, i, l*, 13 diam.; *k*, 100 diam.—(After Hinde.)

Table-cases 13, 11.
Wall-cases 7, 8.

in which their skeletons are built up, Lithistida abound as fossils and are better represented in the Museum than even the Hexactinellida. They are very diverse in form and size, and their spicules also show great variety, some apparently being modified tetraxons, others monaxons, and others polyaxons. It seems therefore that the Order has been derived from both Tetractinellid and Monactinellid ancestors, and its classification is naturally difficult. Pending a satisfactory division into families, the following Sub-Orders are used by palaeontologists:—**Tetracladina** (Cambrian to Recent): desmas four-rayed with their ends produced into twig-like processes which interlock (Figs. 12 *d*, 13 *e, d*); *Aulocopium*, *Siphonia* (Fig. 16 *c*), and *Jerca* are well-known examples.

Eutaxi cladina (Silurian to Jurassic): desma with a Gallery X. thickened central node from which proceed three or more rays, expanded at the ends so as to join others (Fig. 12 *h*); chief genus, *Astylospongia*. **Anomocladina** (Jurassic to Recent): desma a rod with swollen ends from which proceed three or more simple or branched rays, uniting as in Eutaxi-



FIG. 12.—Fossil sponge spicules: Silicispongiae, Tetractinellida. Skeletal spicules of Lithistida. Rhizomorina: *a, b, Seliscothon*; *c, Cnemidistrum*. Tetracladina: *d, Aulocopium megamorina*; *e, f, Doryderma*; *g, Carterella*. Eutaxi cladina: *h, Astylospongia*. *a, b, c, d, h*, enlarged 40 diam.; *e*, 26 diam.; *f, g*, 20 diam. (After Hinde.)

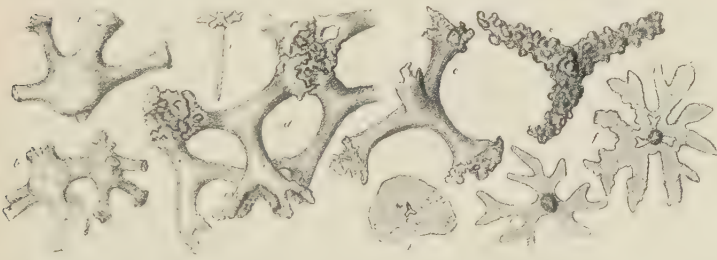


FIG. 13.—Fossil sponge spicules: Silicispongiae, Tetractinellida. Skeletal (*a-e*) and dermal (*f-i*) spicules of Lithistida. Eutaxi cladina: *a, Mastosia*. Anomocladina: *b, Cyli ndrophyma*. Tetracladina: *c, d, Callopegma*; *e, Plinthosella*. *e*, enlarged 26 diam.; the rest 40 diam. (After Hinde.)

cladina (Fig. 13 *b*); *Cyli ndrophyma* is common in Upper Jurassic rocks. **Megamorina** (Silurian to Recent): desmas relatively large, curved, branching rods, either intertwining or joined as in Eutaxi cladina (Fig. 12 *e, f, g*); *Doryderma* (Fig. 16 *b*) is abundant in the Upper Chalk. **Rhizomorina** (Cambrian to Recent): desma small, usually elongate, curved, with irregular branches; these end in minute facets, which

Gallery X. are closely apposed to the axis and branches of adjoining spicules so as to form loosely arranged fibres or an irregular meshwork (Fig. 12 *a, b*); the Cretaceous *Verruculina* (Fig. 17) is characteristic.

SUB-CLASS II. — **MONACTINELLIDA.** Demospongiae with monaxon spicules.

The chief modifications of this simple type of spicule are shown in the accompanying figure (Fig. 14 *a-g*). With



FIG. 14.—Fossil sponge spicules: Silicispongiae, Monactinellida. *a-g* are skeletal, *r, s, t* are flesh-spicules. An open axial canal is shown in *f*; a closed canal in *g*. *a, e*, enlarged 26 diam.; *b*, 100 diam.; *c, f, g, i, j, k, q*, 40 diam.; *d, 66* diam.; *h, m, n, o, r, s, t*, 114 diam.; *l, p*, 13 diam. (After Hinde.)

these are associated smaller flesh-spicules, serving as grapnels in those forms that have a harder outer skin or cortex (Fig. 14 *r, s, t*). In these latter, constituting the Order **Hadromerina** or **Spintharophora**, the spicules are loosely and irregularly arranged. In the other Order, **Halichondrina**, the siliceous spicules are bound into a skeleton by the horny substance spongin. Consequently, though the spicules abound in siliceous deposits, chiefly of Tertiary age, complete sponges are rarely preserved. *Chalina*, *Reniera*, and the freshwater *Spongilla* are among fossil representatives of the Halichondrina. The Hadromerina are important to geologists from including the boring Clionidae, whose tubes are often seen traversing fossil shells; indeed they are also active in the disintegration of rocks.

Table-cases
15, 14.

Table-case
11.

CLASS IV. (?) **OCTACTINELLIDA.**

Silicispongiae, in which the normal spicule has eight rays, of which six radiate in one plane from a common centre, while the other two radiate from the same centre at

right angles to this plane. The Silurian *Astracospongia* is the only genus.

Gallery X.
Wall-case
8B.

CLASS V. (?) **HETERACTINELLIDA.**

Silicispongiae, in which the normal spicule is large, with from six to thirty rays, radiating variously from a common centre (Fig. 8 a). Contains only the Carboniferous *Tholiasterella* and *Asteractinella*.

Table-case
15.

Although the spicules are aberrant, it is often maintained that the Octactinellida and Heteractinellida should be placed with the Hexactinellida.

Turning now to the Table-cases with the **British fossil Sponges**, we find some obscure fragments from the Cambrian Durness Limestone of Scotland, and then the oldest known sponge, *Protospongia fenestrata*, from the Cambrian rocks of St. Davids, S. Wales. All that is preserved are fragments of the meshwork, in which the silica is now replaced by pyrites. They show, however, very primitive triaxon spicules, which enable one to refer the genus to the Hexactinellida Lyssacina. Here also are placed the Silurian *Amphispongia*, *Plectoderma*, and *Hyalostelia*. A specimen of the last shows a root-tuft.

Table-case
15.

The Lower Carboniferous rocks of Yorkshire and Ayrshire have yielded large root-tufts and clearly preserved body-spicules of *Hyalostelia*. Among the other spicules here shown, special note should be taken of the Heteractinellid genera, *Asteractinella* and *Tholiasterella*. Lithistid, Tetractinellid, and Monoactinellid spicules from Ayrshire, and a Calcisponge from Fife are also exhibited.

Table-case
15.

The Calcispongiae first appear in force in a series from the Inferior Oolite, Great Oolite, and Corallian; they form massive or stout branching stocks. The marine Jurassic rocks have also yielded Hexactinellid, Tetractinellid, and Lithistid sponges, while from the Purbeck beds comes a freshwater *Spongilla* to represent the Monoactinellida.



Table-case
14.

FIG. 15. A Calcisponge, *Peronidella pistilliformis*, from Great Oolite near Bath. $\frac{1}{2}$ nat. size.

Among Cretaceous rocks the Lower Greensand of Faringdon, Berks, has long been famous for its beautifully preserved Calcisponges, of which a fine series is shown. The chert beds of this age in Kent and Surrey are mainly com-

Table-case
14.

Gallery X. posed of detached spicules of Tetractinellida and Lithistida. A few larger fragments of the latter group from Sevenoaks are the only representatives of the complete skeleton. From the Gault there are only some specimens of *Terea* and a fine example of the Hexactinellid genus *Craticularia* in pyrites. The Upper Greensand and the Chalk Marl, on the other hand, contain great numbers, which preserve their original form and structure. Those from the Greensand of Warminster, Wilts, first studied by Miss Etheldred Benett of

Table-case 13.

Table-cases 13, 14.



FIG. 16.—Lithistid sponges from the Upper Greensand of Warminster. *a*, *Hallirhoa costata* (specimen 48174); *b*, *Doryderma dichotomum* (specimen P 1260); *c*, *Siphonia tulipa*; a section through the upper part of the sponge, showing the cloaca in the middle near the top, the large excurrent canals which open into it, and the fine incurrent canals leading from the outside to these latter (specimen P 1366). *a* and *b* are reduced to $\frac{1}{4}$ nat. size, and *c* to $\frac{1}{2}$. (After Hinde. See Table-case 13.)

Wall-case 8. that place (1831), are shown in great quantity. Among the Calcispongiae are good specimens of *Pharetrospongia Strahani* from Cambridge. The folded walls of *Plocoscyphia* are conspicuous among the Hexactinellida, but the Lithistid Tetractinellida are the most richly represented. Among these last, particular attention may be directed to the peculiar lobate forms of the Lithistid *Hallirhoa* (Fig. 16 *a*) with long stems, the perfect *Siphoniae* from Blackdown (Fig. 16 *c*), the large goblet forms of *Puchypoterion*, and

Table-case 14.

Table-case 13.

the cylindrical and branching examples of *Doryderma* Gallery X. (Fig. 16 *b*) from near Warminster.

Next follow the sponges from the Chalk, which, though perhaps more numerous, are not so well preserved. Those from the Upper Chalk of the South of England have had their skeletons almost entirely replaced by iron-peroxide; very frequently also they are now enclosed in nodules of solid flint, in part retaining their forms, but their interior structures are merged in the flinty matrix, and only show the course of the larger excurrent canals and the cloacal cavity. Such forms, commonly called Choanites, are represented by the large collection of Toulmin Smith. In the sponges from the Upper Chalk of Flamborough, Yorkshire, the form is usually preserved, and also the main features of the canal system, but the spicular structure is now scarcely recognisable. Calcispongiae are represented by *Elusmostoma* and *Pharetrospongia*, but are not numerous except in the case of the little globular *Poro-sphæra*. The Hexactinellida all belong to the Sub-Class Dictyonina, and among them the best known is the funnel-shaped *Ventriculites* with its folded walls (Fig. 10), but one should notice also the wide flange-like walls of *Guttardia* and the mushroom-shaped *Cocloptychium*. Among Demospongiae, the Choristid Tetractinellida are represented by *Pachastrella* and *Stelletta* and numerous detached spicules of *Geodia* (?). Lithistida are numerous, and here may be observed the large size and the projecting canal-openings in *Stichophyma* and *Verruculina* from the Flamborough Chalk (Fig. 17). Monactinellida include the borings of *Cliona* in Molluscan shells. These last are the only representatives of sponges in the British Tertiary series.



FIG. 17.—*Verruculina Reussi*. Senonian Chalk of Flamborough Head. $\frac{1}{3}$ nat. size.

Table-cases 11, 12.

Wall-case 7A, 7B.

Table-case' 11.

; Passing now to the fossil sponges from foreign localities, exhibited in the Wall-cases, one sees among the Ordovician specimens the large branching Lyssacine Hexactinellid, *Brachiospongia digitata* from Kentucky.

Wall-case 8c.

; The Silurian of North America has furnished the Monactinellid *Climacospongia* and numerous examples of the Lithistid genera *Astylospongia*, *Palaeomanon*, and *Hindia*. The Lithistid *Aulocopium* is from Gotland in the Baltic.

Wall-case 8B.

Gallery X. From this island and from Tennessee comes the noteworthy Octactinellid, *Astracöspongia*.

Wall-case 8c. The Devonian of North America yields casts of *Hydnocerus*, a Lyssacine Hexactinellid. Part of a large sponge-bed, formed of this, is shown in a special case.

Wall-case 8b. From the Triassic strata of St. Cassian there is a series of small Calcispongiae, which have been referred to *Stellispongia*, *Corynella*, and other genera of Pharetrones.

Wall-case 8A, 8B. The Upper Jurassic rocks of Würtemberg and Switzerland, known as the White Jura, contain a large number of Hexactinellida and Lithistida, some layers being mainly composed of these sponges. They retain their outer form, but, in nearly all, the siliceous skeleton has been replaced by calcite. Examples of numerous genera are exhibited.

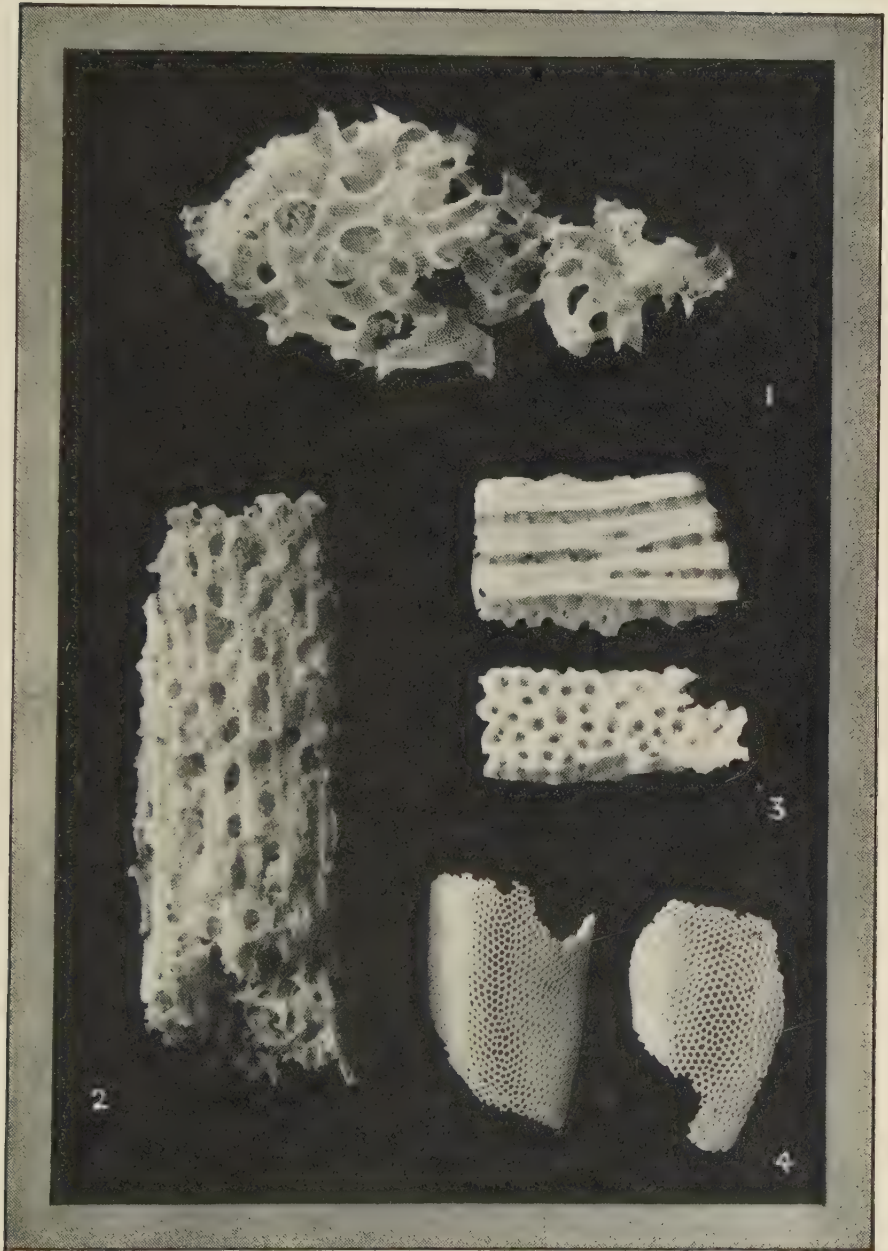
Wall-case 7b. Among the Cretaceous sponges, special notice should be taken of the fine specimens of *Coeloptychium* from the Westphalian Upper Chalk, and of the exquisite series of Hexactinellida and Tetractinellida from the Upper Senonian Chalk of Hanover prepared by Dr. A. Schrammen by carefully

Wall-case 7A. dissolving out the siliceous skeleton from the calcareous rock: alone among fossil sponges do these present the beauty so frequent in the skeletons of recent forms. Those illustrated in the accompanying Plate III are: (1) *Calypptrella tenuissima*; (2) a species of *Rhizopoteron*; (3) *Sporadoscinia Decheni*, the upper figure showing the interior with the canals, into which open the ostia seen in the lower figure; (4) *Aphrocallistes alveolites*.

Wall-case 7A, corner. Tertiary sponges are so rare that one must not overlook the Calcispongiae, *Tretocalix*, *Bactronella*, and *Plectroninia*, which are modified Pharetrones from the Eocene of Australia.

The Trustees issued in 1883 a Catalogue of the Fossil Sponges in the Museum by G. J. Hinde, who has also begun a Monograph of the British Fossil Sponges, published by the Palaeontographical Society (1887, 1888, 1893). See further E. A. Minchin, Section on Sponges in Lankester's "Treatise on Zoology," London, 1900.

Table-case 15. The **Archaeocyathinae** are a peculiar group of organisms found in the oldest fossil-bearing rocks in many parts of the world. Their calcareous skeletons, which built up vast reef-like masses, remind one in some respects of sponges, in other respects of corals. They have also been compared to Algae. Probably they were of animal nature, and independently descended from the Protozoa.



SILICEOUS SKELETONS OF SPONGES FROM THE UPPER SENONIAN CHALK OF HANOVER.
(Slightly enlarged.)

[To face p. 42.]

COELENTERA

The rest of the Gallery is occupied by the fossil COELENTERA (Hollow-guts). This great division of the animal kingdom, which comprises sea-anemones, corals, jelly-fishes, and their allies, owes its name to the fact that the body-wall of each individual encloses a single hollow chamber (not many as in sponges) which forms the digestive cavity of the animal, and is not traversed by any separate gut such as is found in echinoderms and all the other groups that follow. The body-wall consists of an inner and an outer layer of cells, the "endoderm" and "ectoderm" as they are respectively called, and between them a jelly-like layer, the "mesogloea," which is very thick and noticeable in an ordinary jelly-fish. In a jelly-fish, too, one may readily observe that the organs of the body are regularly arranged on lines radiating from the centre (see Fig. 18). A radiate symmetry of this kind is found in most Coelentera. In many Coelentera the individuals or zooids unite to form colonies.

Gallery X.
Table-cases
 1-10.
Wall-cases
 1-6.

Setting aside the Ctenophora, which some exclude from the Coelentera, and of which no fossils are known, the Coelentera may be divided into three classes: Hydrozoa, Scyphozoa, and Anthozoa.

The **Hydrozoa** include the fresh-water polyp *Hydra*, the Hydroid zoophytes such as *Sertularia* the sea-fir, the corals *Millepora* and *Stylaster*, and various forms without fossil allies. All of these have a simple tubular body-wall, enclosing a cylindrical cavity which is, not divided by partitions; the mouth is not pushed inwards; the reproductive cells are derived from the ectoderm and are set free directly to the exterior.

The **Anthozoa** (Flower-animals, also called **Actinozoa** or Rayed animals) include the sea-anemones, nearly all the stony corals, precious coral, sea-fans, sea-pens, and dead men's fingers. In these the mouth is pushed inwards, so as to form a tube; the body-cavity is divided by partitions, called mesenteries, which consist of mesogloea covered with endoderm; the reproductive cells are derived from this endoderm and are set free into the body-cavity whence they pass to the exterior through the mouth.

The **Scyphozoa** (Cup-animals) comprise the larger jelly-fishes. Some place them with the Hydrozoa, which they

Gallery X. resemble in the simple mouth and absence of mesenteries; others place them with the Anthozoa, which they resemble in the origin of the reproductive cells. Other features, however, distinguish them from both these Classes.

CLASS SCYPHOZOA.

Many Coelentera being soft-bodied animals can leave no fossil traces except impressions that they may have formed

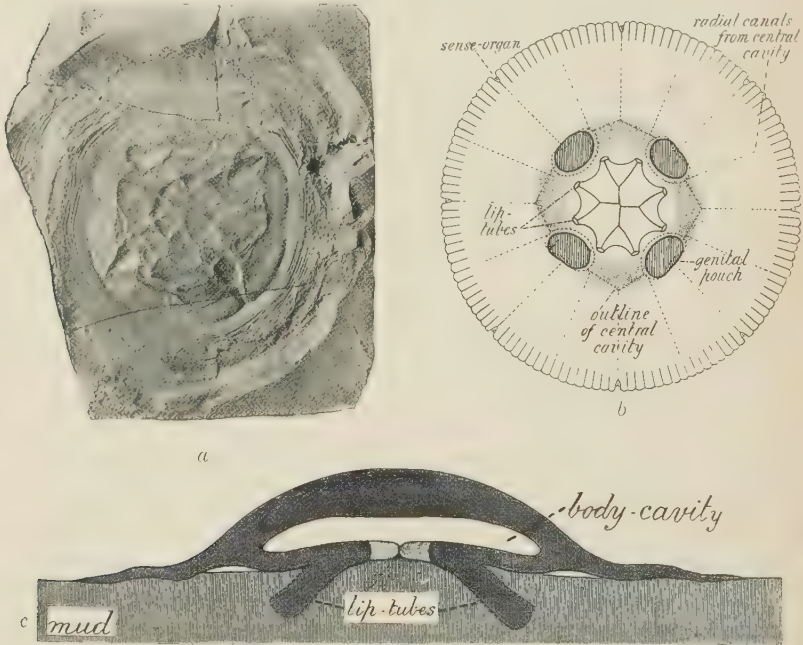


FIG. 18.—A fossil jelly-fish, *Rhizostomites lithographicus*, one of the Scyphomedusae, from the Kimmeridgian of Solenhofen. *a*, imprint on the exposed surface of the Lithographic Stone, about $\frac{1}{4}$ natural size. (From E. Ray Lankester's "Extinct Animals." After Walcott.) *b*, diagram interpreting the marks seen in *a*. (After Brandt.) *c*, diagram to show how the imprint is formed by the jelly-fish settling down on the mud; a vertical cut has been made through the mud and through the middle of the jelly-fish. (After Walcott.)

on a sandy shore; these of course can only be left by free-swimming jelly-fishes or medusae, not by fixed forms. Such impressions are actually known in various rocks from the

Cambrian Epoch onwards, and all appear to belong to a single Sub-Order of Scyphozoa, the **Rhizostomata** (Root-mouths), so called because the four lips of the mouth are drawn out and each fused by its edges into a tube pierced by small openings through which the animal sucks in its food. Examples of such fossils from Cambrian, Ordovician, and Jurassic rocks are exhibited. Among them several large ones from the lithographic stone of Solenhofen, of Kimmeridgian age, resemble that depicted and explained in our Figure 18. Dr. C. D. Walcott has published a full account of fossil jelly-fishes in the Monographs of the United States Geological Survey (1898). Except for these imprints, the Scyphozoa are not known as fossils.

Gallery X.

Wall-case
6c, and
between
7 & 8.

CLASS HYDROZOA.

Among the Hydrozoa many of the colonial forms are protected by a thin horny coat of chitin secreted by the ectoderm and called "periderm." In some this covers the branches of the colony and forms little cups or thecae, into which the polyps can be withdrawn; these are the **Calyptoblastea** (covered buds). In others the periderm does not expand into cups; these are the **Gymnoblastera** (naked buds). An example of the former is the sea-fir, *Sertularia abietina*, often cast on our shores. The periderm has a main stem, with branches diverging from each side alternately; the sides of the stem and of all the branches are clothed with a row of cups or thecae, also in alternate arrangement. In each theca lives a polyp, which stretches out twenty-four tentacles and is connected with its fellows by a cord of flesh that passes inside each branch and down the main stem. It is strange that, though capable of preservation, no traces of the chitinous periderm of any such hydroid should have been found in either Cainozoic or Mesozoic rocks. Not until we pass back to early Palaeozoic times, Cambrian to Devonian, do we find organisms that bear any resemblance to the Calyptoblastea. These, which are called **Cladophora** (branch-bearers) or **Dendroidea** (tree-forms), have numerous slender forking branches, connected by transverse processes, and bearing little thecae, some for the ordinary polyps, others modified possibly for reproductive cells. Some of the genera, such as *Dendrograptus* and *Callograptus*, seem to have been fixed to the sea-floor like a *Sertularia*. *Dictyonema*, however, which forms fan-shaped or funnel-shaped colonies, has been

Table-case
10.

Gallery X. observed to grow up from a sharply-pointed conical cup, the point of which was sometimes attached to a long thread. Such individuals may have been attached to some other animal or plant, but cannot have been directly fixed to the sea-floor. The substance of these fossils is supposed to have been chitinous, like the periderm of Calyptoblastea, when the animals were alive; but actually it is not so. This fact and the absence of any representatives of the group from Devonian to Pleistocene times suggest that, though the Dendroidea may be Hydrozoa, still they cannot be closely related to the Calyptoblastea.

Table-case
10.
Wall-case
6B, c.

Contemporaneous with the Dendroidea, and, some suppose, derived therefrom, is the Order **Graptolitoidea**—the graptolites, a name given by Linnaeus from the likeness which the fossils bear to writing on the slates in which they are usually found compressed. The pointed conical chamber observed in *Dictyonema* is also characteristic of all graptolites, and is called the sicula (Fig. 19). In the growth of a

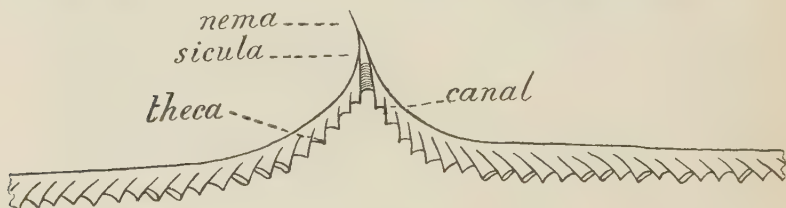


FIG. 19.—An early form of Graptolite, *Didymograptus uniformis*, from the Ordovician of Britain. The sicula consists of a smooth embryonic part, and a later-formed part with growth-lines; similar growth-lines occur on the thecae, but are omitted for the sake of clearness. Enlarged about 3 diameters. (Modified from Elles & Woods.)

colony, a theca (with its contained polyp, be it always understood) budded out from the sicula; and from this theca another budded; and each of these by further budding gave rise to a long line of thecae connected by a common canal. A single branch of such a simple form looks like the blade of a fret-saw, with a straight back, and the thecae forming the teeth, which are directed away from the sicular end. The sicula was almost certainly attached to something, and it is probable that in such forms as these it was attached to floating sea-weed; sometimes it was fixed by a small disc-like expansion; sometimes it hung by a long flexible thread. The earlier graptolite colonies branched many times, e.g. *Bryograptus*; but the number of branches was gradually

reduced, e.g. *Loganograptus*, *Tetragraptus*, until there arose a form with only two saw-blades to a single handle, e.g. *Diphy-mograptus* (Fig. 19). If these hung from sea-weed the polyps would be mouth downwards, a position obviously ill adapted for securing food-particles showered from the floating weed. This was remedied in two different ways. In one way, the two blades, instead of hanging down like a pair of tongs, gradually opened until at last they were directed upwards. In the other way, the polyps of the first two thecae seem to have stretched upwards and so to have bent their thecae in that direction; the rest followed suit, and grew upwards along the thread from which the sicula hung, e.g. *Diplo-graptus*. Thus was formed quite a different type of graptolite. Further developments took place in these latter: the colony acquired a median supporting rod or virgula; this ended often in a disc, which, it is supposed, was hollow, and served as a float. The colonies were often compound, and many vir-gulae with their thecae were attached to a single disc. If the supposition that such forms took to a free-floating existence be correct, we shall understand why succeeding forms, pre-sumably their descendants, should have had their periderm formed of a meshwork of fine strands, e.g. *Retiolites*: this is a well-known way of obtaining lightness without loss of strength.

Such are the main lines of graptolite evolution up to their abrupt end at the close of the Silurian Epoch. But there were many subsidiary lines; and all these, combined with the wide distribution of each successive form owing to its floating life, have rendered the graptolites of enormous value to the geologist in determining the succession of layers in great thicknesses of rock, and in tracing those layers over a large extent of country, even when much disturbed by later earth-movements. A monograph of the British species is in course of publication by the Palaeontographical Society.

* Fossils that can with certainty be referred to the Hydrozoa are very few, and are not older than Cretaceous. They are confined to forms in which the ectoderm secretes outside the polyp or zooid a number of small calcareous rods; these grow together into a solid mass, leaving tubes in which are the polyps. Most of these forms are generally called **Hydrocorallines**, lately divided into *Stylasterina* and **Milleporina**, of which only the latter are found fossil; and, indeed, *Millepora* itself is not known in rocks older than some Pleistocene raised beaches. The Eocene fossil *Aecopora*

Gallery X. The Order **Gymnoblastea** includes both solitary and colonial forms; among the latter the family Podocorynidae contains genera whose roots form an incrustation, somewhat similar to that above described, but without tubes for the polyps; these generally coat gastropod shells. Fossils referred to *Hydractinia*, one of these genera, are found in the Pliocene and Upper Cretaceous rocks of England and elsewhere.

Table-case 9.

Table-case 9.

Wall-case 6c.

There are a number of fossils that present a general resemblance to the massive Hydrocorallines or the encrusting *Hydractinia*, and, in the absence of convincing evidence for or against, they are usually placed with the Hydrozoa. Such are the thick lamellar masses of *Ellipsactinia* and *Sphaeractinia* from Upper Jurassic rocks, the spheroidal *Parkeria* from the Cambridge Greensand and its ally *Stoliczkania*, and some thin incrustations from the Chalk.

Table-cases 9 & 10.

Wall-case 6.

Between Wall-cases 7 & 8.

Apparently allied to some of these forms are the **Stromatopores**, of which a large series is shown in polished slabs of Devonian marble, and a smaller series from the Silurian, both of Britain. There are also several foreign specimens. These fossils usually began by incrusting some solid body, such as a shell, and often grew to enormous size, forming huge banks and reefs. They are composed of calcareous laminae, separated by distinct intervals across which run vertical or radial pillars. Both pillars and laminae are usually traversed by minute irregular canals. The whole mass is in some genera, e.g. *Stromatopora*, perforated by larger tubes, divided by horizontal platforms or tabulae; in these probably lived the principal polyps. The chief work on these obscure fossils is a monograph by H. A. Nicholson, published by the Palaeontographical Society (1886-1892).

CLASS ANTHOZOA.

Among living forms of this Class, a larger proportion have a skeleton capable of preservation in the fossil state. Recent Anthozoa are divided into two Sub-Classes: I. **Alcyonaria**, with 8 mesenteries and 8 tentacles, which bear short branches. II. **Zoantharia**, with 6, 12, 24, or a larger number of mesenteries and an equivalent number of tentacles, which are simple.

The **ALCYONARIA**, with few doubtful exceptions, live in colonies, and the polyps are held together by a jelly (mesogloea). Cells wander from the ectoderm into this jelly,

and, by secreting spicules of a horny substance impregnated with carbonate of lime, give it greater consistency. The common *Acyonium digitatum* (dead man's fingers) has such a skeleton; it falls to pieces on the death of the animal, but isolated spicules have been found fossil. Sometimes the spicules become tightly wedged together and form a compact skeleton which cannot be disintegrated; the precious coral (*Cocallium rubrum*) is the hardest skeleton so formed, but has only been found fossil in some of the later rocks, and that rarely. The organ-pipe coral (*Tubipora*) is also well known, but is not found fossil. Some of the Gorgonacea form an axis partly horny and partly calcareous; and some calcareous segments referred to *Isis*, and a few other forms have been found in Tertiary and Cretaceous rocks. A horny axis supports the colony of the sea-pen, *Pennatula*, and in some allied forms this axis is partly calcified; a few such axes have been detected in Triassic and later rocks. In the living *Heliopora*, the skeleton is formed, not from spicules developed in cells, but from lamellæ of calcite crystallised in an organic matrix produced by the disintegration of ectoderm cells. This genus is found fossil back to the Albian Age. With the exception of a supposed Triassic Pennatulid, fossils that can with certainty be referred to Alcyonaria are confined to rocks of Upper Cretaceous and later age; and yet, as was the case in Hydrozoa, there are a number of Palaeozoic genera that resemble many of the recent forms.

Gallery X.

Table-case
1.

In the Sub-Class **ZOANTHARIA**, the only living forms with a skeleton capable of fossilization are several genera differing a good deal in their structure but conveniently grouped together as **Madreporaria**. Several of them might be roughly described as sea-anemones with a skeleton. This skeleton is quite different from that of the Alcyonaria, except perhaps *Heliopora*. It consists of crystalline carbonate of lime secreted by special ectoderm cells, not within the cells but outside them, and outside the whole of the ectoderm. The skeleton of the Alcyonaria is internal, that of the Zoantharia is external, as is the shell of a snail. When the young coral-embryo settles down on the sea-floor, it deposits a layer of skeletal substance between its skin and the sea-floor, forming a plate, which soon is turned up at the edges like a saucer. The soft body of the coral may be wholly supported within the saucer, or it may pass beyond its rim. In either case the rim is still built up, and at the same time laminae of lime stretch out from it to the centre

Gallery X. of the floor, each lamina corresponding to a space between two mesenteries; then the lamina itself is built up and so forces the skin inwards into the said space. Thus the skeleton takes the shape of a cup or calyx, partly divided by vertical partitions called septa. Other growths from the wall or from the floor of the cup may be formed in like manner. These are: a single spike or column in the centre, called the "columella"; columns between the ends of the septa and the centre, called "pali"; ridges outside the wall, corresponding with the septa inside, and called "costae." As the calyx grows upwards, the polyp is sometimes pulled away from the bottom of it, but does not therefore stop the secretion from its skin; if a small piece only is pulled away from one side, the skin builds here an oblique partition called a "dissepiment;" if the whole base is pulled away, it deposits a horizontal or saucer-shaped, or sometimes funnel-shaped, partition called a "tabula." Such is the general structure of a solitary cup-coral. Corals may form colonies, either by the repeated budding of such a single form or by its dividing down the middle into two, each half again dividing, and so on. This process of fission, as it is called, is sometimes incomplete, and so arises a form like the Brain-coral, in which the cavities of the polyps and of the cups remain connected in serpentine grooves (Fig. 24). There is much the same difficulty in connecting Palaeozoic genera with the Madreporaria of Tertiary and recent date, as we have already seen attaching to other groups of Coelentera. Similarly the modern reef-builders, Madreporidae and Poritidae, first appear in Tertiary rocks. Consequently the classification of the Order is far from settled. By means of the skeleton it is possible to divide the genera into three groups: *Aporosa*, *Fungacea*, and *Perforata*. The *Aporosa* are so called because the calyx-wall and the septa are not perforated by canals, and in colonial forms the polyps are either separate or connected only by superficial canals. The *Fungacea* include all forms like *Fungia*, whose skeleton has so many septa that it looks like the under side of a mushroom; the long thin septa of these forms are strutted by short cross-bars. The name *Perforata* is given to corals in which the skeletal substance is porous throughout, and the polyps of a colony are connected by deep-seated canals. It is not pretended that these groupings indicate relationship. Another method of division is according to the arrangement of the septa. In later Madreporaria these conform to the

general Zoantharian type, and are in multiples of 6. In many Palaeozoic corals they are in multiples of 4. The former have therefore been called **Hexacoralla**, and the latter, **Tetracoralla**. The wall of the Tetracoralla is often wrinkled, so that they have also been called **Rugosa**. Gallery X.

Owing to the difficulties of classification, all the fossil Anthozoa are placed together and arranged under the chief stratigraphical divisions, the British and foreign specimens being separated as usual. Table-cases
1-9.
Wall-cases
1-6.

Beginning with the oldest, we find **Ordovician corals** from the Llandeilo rocks of North Wales and the Stinchar Limestone of Scotland. *Streptelasma* belongs to the Zaphrentidae; *Lyopora* is allied to *Favosites*. These fossils are ill-preserved, and the genera will be better studied later. Table-case
9.

The British **Silurian corals** are mainly from the Wenlock Limestone. First come a number of genera placed in the family Favositidae, though not all with equal reason. *Favosites*, the honey-comb coral, itself consists of five- or six-sided tubes, set closely together; each tube is divided by flat tabulae, and its cavity is in connection with that of its neighbours by small pores in the wall. *Syringolites*, a North American genus of the same age, has a similar structure, but its tabulae are funnel-shaped (Fig. 20). Some regard Table-case
8.

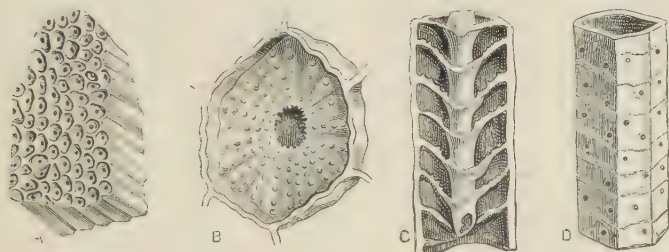


FIG. 20.—A Favositid Coral, *Syringolites huronensis*, from the Silurian of North America. A, a fragment of a colony, natural size. B, a single calyx enlarged 8 diameters; the tabula bears tubercles in radiating lines, like the beginnings of septa, and is sharply bent downwards near the centre. C, a single tube split longitudinally and enlarged 6 diam.; shows the funnel-shaped tabulae. D, a single tube seen from the outside and enlarged 6 diameters; shows the mural pores that connect the cavities of adjoining corallites. (After Hinde.)

these genera as related to *Alveopora*, a modern perforate madreporarian. Others compare them with *Syringopora*, also shown in the Silurian series, but better studied in its

Gallery X.
Table-case
8.

Carboniferous species (Table-case 5). Here the tubes are separate, but connected by cross-canals, and the tabulae are funnel-shaped (Fig. 22, *b*). The living alcyonarian, *Clavularia*, has a tubular skeleton with similar cross-canals, and the organ-pipe coral, *Tubipora*, has tabulae either flat or funnel-shaped and cross-canals running in the flat expansions that connect the tubes; therefore many place *Syringopora* and the Favositidae with these Alcyonaria. In all these genera the tubes of each colony are of equal size, and doubtless contained equally developed polyps. On the other side of this Case is *Heliolites* (sun-stone), in which the surface shows openings like little suns surrounded by smaller circular openings; in section the colony is seen to be formed of tabulate tubes of two sizes. *Heliolites* and its allies are explained by reference to *Heliopora* (see Table-case 1), a living Alcyonarian, in which the larger tubes contain complete polyps, and the smaller ones contain simple sacs of the common flesh of the colony. *Halysites*, the chain-coral (Fig. 21 *a, b*), consists of tabulate tubes, flattened, and joined

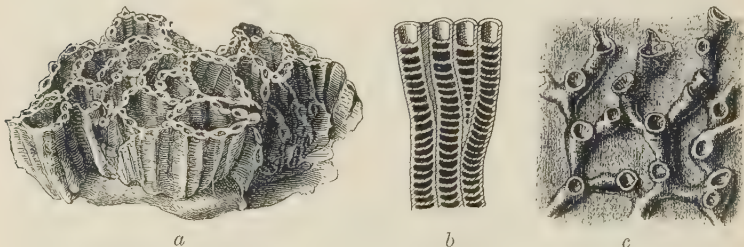


FIG. 21.—Silurian Anthozoa, possibly Alcyonaria, from the Wenlock Limestone of Dudley. *a*, *Halysites catenularius*, natural size; *b*, some of its tubes seen in section, to show the tabulae, slightly enlarged; *c*, *Aulopora*, growing on a shell, enlarged $\frac{3}{8}$ diameter. (From specimen R 2067, Table-case 8.)

by their edges, with no connecting pores; in some species all tubes are of equal size, in others some tubes are much smaller; it is probably an Alcyonarian. *Aulopora*, apparently an ally, grows in a low network over shells and corals (Fig. 21 *c*). A slab of Silurian limestone from Gotland, between Wall-cases 5 and 6, is largely composed of *Favosites* and *Halysites*.

Table-case
7.

In the next Case are Silurian Zoantharia Rugosa or Tetracoralla. Here come the conical *Omphyma* with root-like supports (Fig. 22 *a*), the broadly spreading cups of

Ptychophyllum, the disc-shaped *Palaeocyclus*, the massive colonies of *Strombodes*. In the next compartment is *Cystiphyllum*, in which the lower part of the calyx is divided by dissepiments into a vast number of tiny chambers or cysts. In the allied *Goniophyllum* and *Rhizophyllum* the calyx was closed by a movable lid. On the other side of the Case is *Cyathophyllum*, some specimens of which show several young budding from the calyx of the parent. Last is the allied colonial form *Acervularia*.

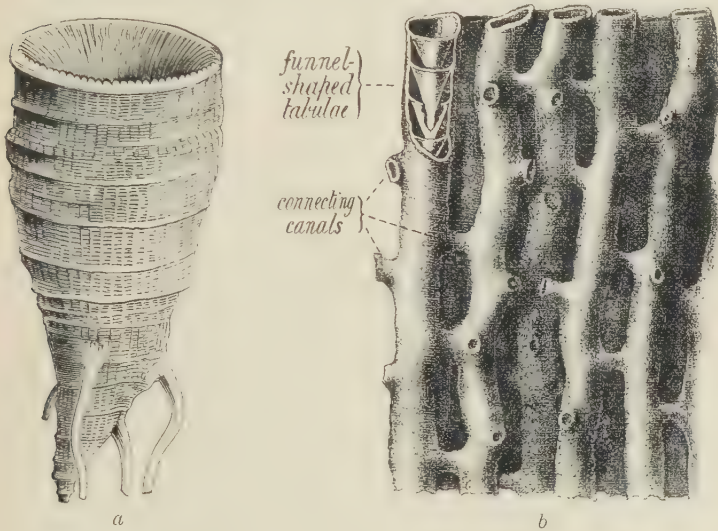


FIG. 22.—Palaeozoic Anthozoa. *a*, a Rugose Zoantharian Coral, *Omphyma subturbinatum*, from the Wenlock Limestone. About $\frac{1}{2}$ natural size. (From Prestwich's "Geology.") (See Table-case 7.) *b*, a supposed Alcyonarian, *Syringopora ramulosa*, from the Carboniferous Limestone of Yorkshire. Enlarged 3 diameters. (Table-case 5.)

Of the **Devonian corals**, the Favositidae fill the rest of Case 7. Here is *Pleurodictyum*, frequently associated with a worm, as better seen in the specimens from the Eifel; a similar association is common in *Heliopora*. These and the Devonian Zoantharia are mostly of the same genera as the Silurian corals; but they grew more luxuriantly in reefs, which now form the massive limestones of Eifelian age in South Devon. Here the specimens have to be studied in polished sections, some of which are of great beauty; one may particularly note *Pachypora cervicornis* in the black

Table-case
7.
Wall-case
5A.

Table-case
6.
Slab
between
Wall-cases
4 & 5.

Table-case
6.

Gallery X.
Wall-cases
4c & 5.

Wall-case
4c.

limestone of Newton Bushel, *Smithia Pengellyi* in the pink and grey reefs of Barton, and the massive *Cyathophyllum helianthoides* in the red rocks of Torquay and Plymouth. In the corner of Case 6 are specimens of *Calceola sandalina*, better shown in the Eifel series; this is allied to *Rhizophyllum*, and, from its triangular shape and large lid, closely resembles some brachiopods (Fig. 23).

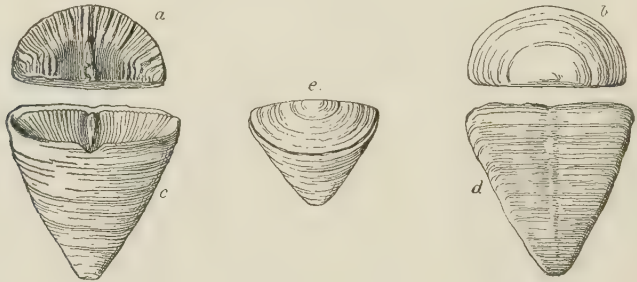


FIG. 23.—A Devonian Operculate Coral, *Calceola sandalina*. *a*, the inside, and *b*, the outside of the operculum; *c* and *d*, corresponding views of the calyx; *e*, a specimen with the operculum closed over the calyx. Slightly less than natural size. (See Wall-case 4c.)

Table-cases
4 & 5.
Wall-cases
3 & 4.

Table-case
5.

Between
Wall-cases
3 & 4.

Table-case
4.

Wall-case
4.

Between
Wall-cases
3 & 4.

The **Carboniferous corals** are the last of the Palaeozoic type. The foreign collection includes specimens from Arctic America, from Tournai and Visé in Belgium, and several brought from the Ural Mountains by Sir Roderick Murchison. Among the British Favositidae are the curious little *Palaeacis* and a good series of *Syringopora*. Close by is *Monilopora crassa* growing on crinoid stems, which become deformed in the attempt to grow over it. *Chaetetes*, which follows, is referred with doubt to the Alcyonaria. On the other side of the Case come *Amplexus* and *Zaphrentis*, showing marked bilateral symmetry in the arrangement of their septa, such as obtains in the mesenteries of the recent Zoanthidae, which have no skeleton. In *Amplexus* the septa are reduced in size, but tabulae are strongly developed. There follow several genera of Madreporaria Aporosa: the cylindrical *Campophyllum*, which may grow to a great length, as shown by specimens from Weston-super-Mare; *Lonsdaleia* and *Lithostrotion*, whose prismatic tubes build up large colonial masses, as those of the familiar *Lithostrotion basaltiforme* and of *L. irregulare* from Fermanagh; *Dibunophyllum*, of stratigraphical importance, shown also on a fine slab from

Durham; *Cyathophyllum*, largely represented in the Table-case, and by some polished slabs of *C. regium* from Bristol; *Clisiophyllum* and *Aspidophyllum*, which end the series. Henceforward these Tetracoralla disappear from the rocks; but the living *Astraeid* coral, *Moseleya*, has when young a four-rayed symmetry which suggests relationship to the *Cyathophyllidae*. It is possible that the latter forms were the ancestors of the *Astraeidae*.

Gallery X.
Wall-case
4.

Neither **Permian** nor **Triassic corals** are represented in the British series, but there are shown specimens from the Zechstein, as well as the Klipstein collection from the Triassic beds of St. Cassian in the Tyrol.

Wall-case
3.

The next coral fauna represented in the British islands is that of the Lias, the earliest of the **Jurassic corals**. This

Table-case
4.

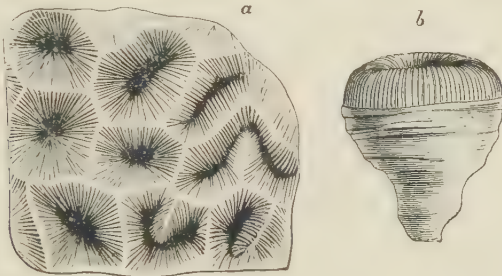


FIG. 24.—Zoantharian Corals of Bajocian Age, from the Inferior Oolite of England. *a*, "*Latomæandrea*" *Flemingi*. *b*, *Montlivaltia trochooides*. (From Prestwich's "Geology.")

shows a great change; all the Palaeozoic genera have given place to normal representatives of existing families and genera, such as *Isastraea* and *Montlivaltia* (Figs. 24 *b*, 25 *b*). The collections from the Inferior Oolite are richer, and the representatives of modern genera are increased by Fungians, such as *Thamnastraea*, and also by a doubtful species (Fig. 24 *a*) representing the confluent *Astraeids*, in which the polyps and calyces are incompletely separated as in the Brain-coral. In the rocks of Bathonian age are many corals of similar type, the chief reef-builder being *Calamophylla radiata*. In the Corallian rocks true reefs are formed of *Thecosmilia*, *Thamnastraea*, and *Isastraea*, of which large specimens are shown (Fig. 25). The structure of all these Jurassic corals, as of the succeeding Cretaceous and Tertiary genera, can be gathered from the diagrams placed in the Table-cases. An interesting series is that of *Isastraea oblonga*,

Table-case
3.

Table-case
2.

Wall-case
3.

Gallery X. from the Portlandian of Portland and Tisbury, showing how the skeleton of the coral has been converted into chert in varying degrees.

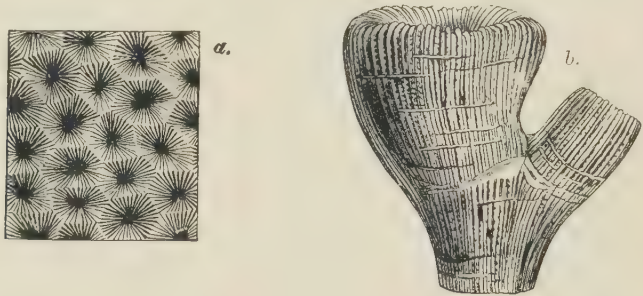


FIG. 25.—Zoantharian Corals of Upper Corallian Age, from Wiltshire. *a*, *Isastræa explanata*; *b*, *Thecosmilia annularis*. Natural size. (From Prestwich's "Geology.") (See Table-case 2.)

Table-cases
1 & 2.

In the **Cretaceous Epoch**, corals were scarcer in England, for the conditions were less favourable to their growth. The faunas from the lower rocks are in Table-case 2, those from the upper rocks in Case 1. From the Lower Greensand comes *Holocystis elegans*, once regarded as the only Rugose coral of later age than Palaeozoic. In spite, however, of its four-rayed symmetry, it is now regarded as a normal *Astræid*.

In the Gault and Chalk, the principal corals are small, simple forms, for the mud of the former, and the cold depths

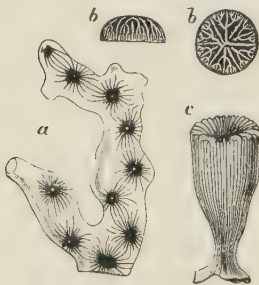


FIG. 26.—Zoantharian corals from the British Chalk. *a* and *c* are *Madreporaria Aporosa*: *a*, *Synhelix Sharpei*; *c*, *Paramsmilia centralis*. *b* is a *Perforate Madreporarian*, *Stephanophyllia Bowerbanki*. Nat. size. (From Prestwich's "Geology.") (See Table-case 1.)

of the latter sea were fatal to reef-builders. The commonest type is conical in shape, such as *Smilotrochus* and *Paramsmilia* (Fig. 26 *c*); some specimens of the latter have been split and show the structure of the calyx clearly. Occasionally

Parasmilia is elongate and cylindrical. *Onchotrochus serpentinus* is as narrow and sinuous as a worm-tube. Other forms are discoid, such as *Cylocyathus Fittoni* from the Gault, *Trochocyathus Harveyanus* from the Cambridge Greensand, and *Microbacia coronula* from the Chalk. Gorgonians are represented in the Chalk by *Acogaster cretacea*. The series of corals from the Upper Greensand of Haldon in Devonshire, recently enriched by the Vicary Collection, contains many specimens described by P. M. Duncan in a Monograph of the Palaeontographical Society. Here may be noticed *Haldonia*, *Placosmilia*, and excellent specimens of *Helipora*. The Foreign Jurassic and Cretaceous collections chiefly illustrate the faunas of Central Europe.

Among the British **Cainozoic corals** the Eocene and Oligocene fauna is separated from that of Pliocene age. Here first appears the family of reef-building Zoantharia Perforata, the Poritida (Fig. 27 c), of which a Catalogue by

Gallery X.
Table-cases
1 & 2.

Wall-cases
2 & 3.

Table-case
1.

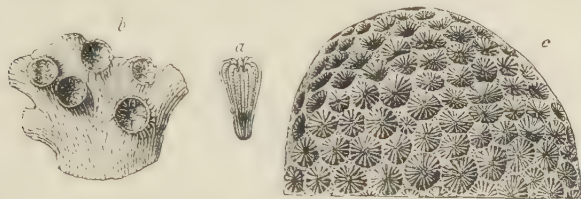


FIG. 27.—Perforate Zoantharian corals from the Lutetian of Bracklesham. a, *Turbinolia Dixoni*; b, *Dendrophyllia dendrophylloides*; c, *Goniopora Websteri*. Natural size. (From Prestwich's "Geology.") (See Table-case 1.)

H. M. Bernard has been published. *Stephanophyllia*, *Dendrophyllia* (Fig. 27 b), and *Balanophyllia* are also Perforata. The adjoining *Stylococenia* is an *Astracoid*. Then come the characteristically modern *Turbinolidae* (Fig. 27 a), and the branching *Oculina*. *Alcyonaria* are represented by the axis of a sea-pen named *Graphularia Wetherelli*, and by the gorgonians *Websteria* and *Mopsea*, allied to *Isis*. The Pliocene Crags have yielded a few small corals of no great interest. The foreign series of Cainozoic corals includes representatives of the Indian faunas and many type-specimens of species from the West Indies.

Wall-cases
1 & 2.

In illustration of the rock-forming activities of corals there is placed in the centre of this Gallery a Case with specimens of the core obtained by a deep boring on the coral island of Funafuti, and other specimens showing the rate of growth of various corals.

**Gallery
VIII.**

We pass now to Gallery VIII, which contains fossils belonging to several of the great divisions of the animal kingdom. These are arranged in the following order, beginning on the right of the entrance and continuing down the east side of the Gallery, and then crossing to the west side: Echinoderma, Annelida, Arthropoda, Brachiopoda, Bryozoa, and Mollusca (except Cephalopoda). These groups will now be taken in that order.

ECHINODERMA.**East Side.**

The Sea-Urchin, the Starfish, the Brittle-Star, the Feather-Star, and the Sea-Cucumber, all of which live in modern seas, are examples of this subkingdom. Though differing from one another in outward appearance, they resemble one another and differ from the rest of the animal kingdom in a number of characters which are briefly stated in a label on the wall near the entrance. For further information as to the anatomy and general appearance of forms now living the visitor should consult the Starfish Gallery of the Zoological Department and the Guide relating thereto.

The examples mentioned above represent each one of the Classes into which this subkingdom is generally divided. Taking them in the same order, these are Echinoidea, Asteroidea, Ophiuroidea, Crinoidea, and Holothurioidea. Remains of all these are found as fossils, and there are also at least three Classes, now extinct, and only known from fossils in Palaeozoic rocks. They are called Cystidea, Edrioasteroidea, and Blastoidea.

CLASS CRINOIDEA.

**Table-cases
32, 31.
Wall-cases
18, 17, 16.**

This Class comes first in the present arrangement of the Gallery. Specimens of some Recent species are placed in the Wall-case close to the entrance, and their flower-like appearance enables one to understand why these beautiful animals should be called by this Greek word, meaning Lily-shaped, and by the popular name Sea-lilies. Though they bear this name, and though many of them have a long stalk and may be fixed to the sea-floor, still they have nothing whatever to do with plants, but are highly organised animals, with a distinct digestive system shut off from the main-body cavity, with nerves, with blood-vessels, and with

a peculiar hydraulic system of water-vessels. The **structure of the Crinoidea** is illustrated by a series of specimens and drawings, with special reference to fossil forms, and study of this may serve as further introduction to the Echinoderma in general.

Gallery
VIII.
Table-case
32.

The first point to notice is that in crinoids as in all echinoderms, with one or two exceptions, the soft tissues of the animal have the power of depositing crystalline carbonate of lime. This may remain in the shape of minute separate spicules; or the spicules may grow together into a trellis-work, which forms rods and plates. The deposit is usually most abundant in the skin, where it may be built into a continuous skeleton. Often too, spines of the same substance are borne outside the test. This feature, rare in crinoids but characteristic of the sea-urchin, has given to the sub-kingdom its name Echinoderma, which is a Greek adjective meaning "urchin-skinned."

Table-case
32.

The chief parts of the Skeleton of a Typical Crinoid are next shown, and are further illustrated by the accompanying figure (Fig. 28). What one may call the body of the animal is confined to the small portion labelled "cup," on the top of which is the mouth. Since the creature does not move about, it needs some means of bringing food to the mouth, and this is provided by the arms. These are grooved on the inner surface, and water containing the animalculae on which the crinoid feeds is swept down the grooves to the mouth. The stem serves to raise the cup and arms away from the sea-floor and to sweep them through a larger field of food-supply.

Perhaps the Crinoidea are descended from animals that were neither fixed nor provided with a hard skeleton. In any case the result of fixation has been with these creatures, as with so many others, the development of radiate symmetry, caused originally by the food-grooves stretching out from the mouth in all directions. Apparently for mechanical reasons connected with the existence of a hard skeleton, the chief planes of this symmetry have come to be five in number. In other words the skeleton, and to some extent the soft parts and internal organs, can be divided into five similar portions grouped about a central axis. This division into fives or pentamerism, as it is termed, runs right through the Crinoidea and Blastoidea and all the free-moving Echinoderms, although modifications of it arise now and then. It should be understood that the forking of the arms is no modification.

Gallery
VIII.

since the arms remain only five however many times each may branch.

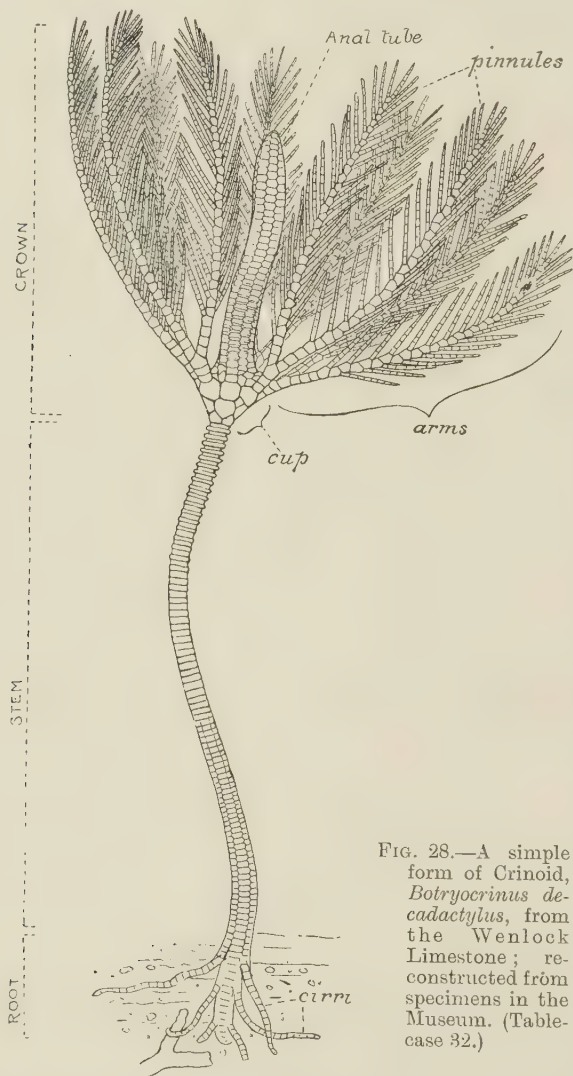


FIG. 28.—A simple form of Crinoid, *Botryocrinus decadactylus*, from the Wenlock Limestone; reconstructed from specimens in the Museum. (Table-case 32.)

The arms serve not only for collecting food but also for respiration. The hydraulic system already mentioned extends

along each arm and arm-branch, in the form of a tube or water-vessel, shown in some of the diagrams exhibited. This gives off side-branches to little thin-walled tentacles, which serve as gills and as sense-organs. When touched they withdraw and the groove is closed over by the little covering-plates that are generally present. They are again extended by the pressure of the water in the hydraulic system, and this system is kept full of water by means of openings in the covering or lid of the cup, through which water is swept by minute vibrating lashes (cilia); frequently these openings are confined to a single sieve-like plate, the madreporite. One can understand how this system also was developed in connection with a fixed mode of life. But its importance, like that of the five-rayed symmetry, is due to the fact that it is also found in the free-moving Echinoderms. For these and other reasons it has been supposed that the chief characters of the Echinoderms as we know them in modern seas are due to their descent from a fixed ancestor.

Gallery
VIII.

We may now pass on to the **general series of fossil Crinoids**. The British specimens are grouped under Early Palaeozoic, Devonian, Carboniferous and Permian, Jurassic, Cretaceous, and Tertiary. The foreign specimens are under the same stratigraphical divisions, to which, however, the Trias is added. Some larger British specimens are also in these Wall-cases, and Wall-case 16 contains large slabs from both British and foreign localities.

Table-cases
32-31.

Wall-cases
17, 18.

Wall-case
16.

Most of the British **Lower Palaeozoic Crinoids** consist of the varied series of forms from the Wenlock Limestone of Dudley. Here one may compare the specimens of *Botryocrinus* with the restoration (Fig. 28), and may note how pinnules are gradually evolved from simply forked arms. Adjoining are *Mustigocrinus*, with its long scourge-like arms, and *Thenarocrinus*, both with a large extension of the cup-lid looking like a wicker-basket; this is the ventral sac, through which passed the end of the gut. *Herpetocrinus* is a curious form in which the stem coiled round the cup when the animal was at rest or dead, so that the fossils look like ammonites. In *Calceocrinus* the arms of one side increase in size while the others gradually disappear, so that the five-rayed symmetry of the cup is also partly lost, and the crown hangs down from the stem, looking like the head of some large-billed bird. *Cyathocrinus* and *Gissoocrinus* are simple types, from which *Enalloocrinus* is not far removed. By the union of the arm-branches in such a form arose *Crotalocrinus*

Table-case
32.

Gallery VIII. with its net-like arms, and *Petalocrinus* with each arm like a solid fan. Then come crinoids in which the food-grooves were covered over and sunk beneath the covering of the cup; these are called Camerata or vaulted crinoids. Among them *Periechocrinus*, with its large cup and bead-like stem, is the commonest. In *Eucalyptocrinus* wing-like processes grew up from the lid of the cup and formed recesses into which the arms were received when folded. Slabs containing many of these crinoids are on the lowest slope of Wall-case 18, and show how in those days many forms belonging to different genera and species lived close together. Here are also several specimens from N. America and Bohemia. The most remarkable is *Scyphocrinus*, which had an enormous and apparently top-heavy crown; its stem, however, was attached to a large hollow ball (the Lobolith of Barrande) which probably served as a float, so that the crinoid hung crown downwards.

Table-case 32.

Wall-case 17.

The British **Devonian Crinoids** are not well preserved. *Hexacrinus* is the most conspicuous. Some foreign ones are in the Wall-case, but the most remarkable are the slender forms preserved in pyrites, from the Lower Devonian slates of the Rhine district.

Table-case 31.

The British **Carboniferous Crinoids** come mostly from the neighbourhood of Bristol, from Derbyshire, Yorkshire, and Lancashire. Most of these are Camerata, among which *Actinocrinus* and *Amphoracrinus* are well-known types. The type-specimen of *Actinocrinus loricatus*, Schlotheim, is of interest as the first British crinoid calyx ever figured, and as having a longer history than almost any other specimen in this Museum. Described by J. Beaumont in 1676 as a root, it was called the Nave Encrinite by J. Parkinson (1808) and wrongly referred to *Actinocrinus triacontadactylus* by J. S. Miller. Another common genus is *Platycrinus*. The crinoids of this epoch are even more abundant in North America, and some exceptionally fine specimens are shown. One may note *Gilbertocrinus* with its strange drooping appendages, the spiny *Dorycrinus*, and *Eucladocrinus* with a twisted stem like that of *Platycrinus*.

Wall-cases 17 & 18.

Wall-case 17.

Triassic Crinoids are not found in Britain, but are fairly abundant in the Tyrol and in Bakony, from both which places the Museum possesses excellent series. The best known form, however, is the Lily Encrinite, *Encrinus liliiformis*, from the Muschelkalk of Germany.

Conspicuous among **Jurassic Crinoids** is *Pentacrinus*, of



A SLAB OF LIAS SHALE FROM BOLL, IN WURTEMBERG, COVERED WITH THE REMAINS
OF A LARGE CRINOID, *Pentacrinus Hiemeri*.

[To face p. 63.]

which many magnificent examples from Lyme Regis and elsewhere are exhibited. Here we note how colonies were formed of many individuals of only one or two species, as is the case to-day. A portion of such a colony from the Lias of Boll, in Würtemberg, forms a beautiful picture in the middle of the case (Plate IV). The stem of this form is said to reach a length of 50 feet; a length of 15 feet is certainly common. The length of stem is perhaps to be explained by the fact that many of these Liassic *Pentacrinini* were attached to floating pieces of wood, and so hung crown downwards. A closely allied form is *Isocrinus*, which grows in forests on the floor of some recent seas. Various species will be found among the Triassic, Jurassic, Cretaceous, and Tertiary crinoids. The elegant five-petalled stem-segments of both these genera are washed out of the rocks in many places, and to them the name *Pentacrinus* (five-lily) was first given by Agricola in 1546. The Pear Encrinite (*Apiocrinus*) from the Bradford Clay of Wiltshire has the top part of its stem greatly thickened. Near it is *Millericrinus Pratti*, which exemplifies the tendency, constant in crinoids, to loosen their attachment to the sea-floor and to become free-moving, with a shortened stem. The stem is reduced to a mere knob in *Antedon* and *Actinometra*, which, beginning in the Oolites, occur in vast numbers in modern seas. Though unstalked and free-moving when grown up, these crinoids are fixed by a stalk when quite young.

In the **Cretaceous Crinoids**, *Marsupites* and *Uintacrinus*, the stem is entirely lost, and it seems probable that the latter at all events was a free-swimming form. Both genera lived at almost the same time (Upper Senonian) and were widely distributed. Specimens are shown from the English Chalk, and a slab covered with *Uintacrinus* from North America is placed on the wall.

Tertiary Crinoids are not numerous. The most interesting specimens are those illustrating variation in the stem of *Balanocrinus*, another Pentacrinid.

Gallery
VIII.
Wall-case
16.

Wall-case
18.
Table-case
31.

Table-case
31.

Between
Wall-cases
16 & 17.

Wall-case
17.

CLASS CYSTIDEA.

The Cystids are of interest partly on account of their rarity, partly because they are all extinct, none having survived the Carboniferous Epoch, partly by reason of their diversity and strangeness of structure, but mainly because they are thought to comprise forms from which other classes

Gallery
VIII.
Table-case
30.
Wall-case
18.

of Echinoderma have descended and to approach most nearly those pre-existing animals from which the Echinoderma were originally derived. The best British specimens are from the Wenlock Limestone; but other horizons are well represented by those from Bohemia, Russia, North America and other foreign countries. Among the older and more primitive are many, such as *Aristocystis* (Fig. 29 *a*), that appear to have been little more than plated sacks, without stem or arms:

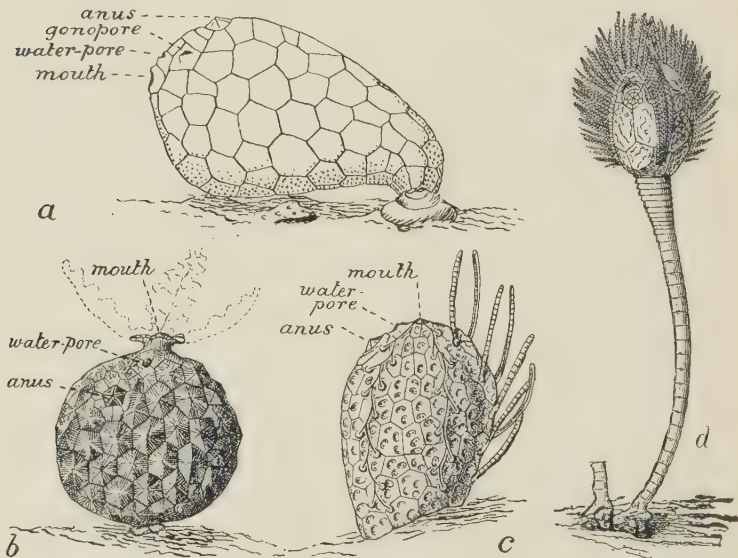


FIG. 29.—Types of Cystidea. *a*, Sack form with scattered pores, *Aristocystis*. *b*, Example of Rhombifera, with food-groove skeleton slightly developed, *Echinospaera*. *c*, Example of Diploporita, *Protocrinus*; the brachioles are restored on the right side; elsewhere are seen the facets that supported them. *d*, Example of Rhombifera, with food-groove skeleton highly developed, and with respiratory folds restricted to three “pectini-rhombs,” of which one is shown near the top of the right-hand quarter; *Lepadocrinus*.

hence the name of the class, which means “sack-shaped.” These, however, probably all had ciliated food-grooves stretching from the mouth, either along fleshy tentacles or along similar processes provided with a calcified support or skeleton. These processes are called brachioles, and there is no reason to suppose that they contained such extensions of the body-cavity, of the reproductive organs, or even of the hydraulic system, as occur in Crinoidea. Hence we suppose that a

special opening found in the hard body-wall of these forms served for the extrusion of the eggs; and we infer that the necessary process of respiration was effected by means of the pores which penetrate the plating of the sack or theca. Feeding and breathing are the two processes without which the life of an animal must stop, and the history of the Cystidea, as of most groups of animals, is the history of changes by which these processes were ever better and better carried out. Let us briefly contrast in these respects the two forms of the Crystal-apple, as the Swedes call a fossil so common in their country and found also in our Welsh Ordovician rocks, namely *Echinosphaera* (Fig. 29 *b*) and *Sphaerocrinus*, or the more advanced *Protocrinus* (Fig. 29 *c*).

The numerous plates of *Echinosphaera* appear to be joined by fine lines, which represent canals in their substance and are arranged in rhombs. In *Sphaerocrinus* and *Protocrinus* a number of small ovals are scattered over the plates, and each of these contains two vertical canals meeting near the inner surface. Both of these structures appear to have contained spaces that brought the soft tissues and interior fluids of the animal close to the outer aerated sea-water. In *Echinosphaera* the food-grooves were borne entirely on separate skeletal pieces; in *Protocrinus* they pass over the surface of the plates before reaching the brachioles. Turn next to the Wenlockian *Iepadocrinus*, of which a reconstruction is here drawn (Fig. 29 *d*), and note that the canals joining the plates are now visible only in three places, where they are intensified as deep folds; here too the food-grooves are carried far over the surface on a series of special pieces from which the brachioles arise; to keep these away from the mud, the whole body is now raised on a stem. This then is a development of the *Echinosphaera* type. The other line of evolution leads to a form like *Proteroblastus*, in which there are five food-grooves passing right down the actual surface of the plated sack or theca, and bordered regularly by brachioles; the double canals are here concentrated on the plates that bear the brachioles. On these two distinct lines of evolution are based the two Orders: **Rhombifera** (with canals or folds in rhombic pattern) and **Diploporita** (with canals opening in double pores).

Notable Cystidea, perhaps to be regarded as a distinct Order, are the **Anomalocystidae**, of which *Trochocystis*, *Mitrocystis*, and *Placocystis* respectively represent the Cambrian, Ordovician, and Silurian stages of evolution. The two

Gallery
VIII.

Wall-case
18.
Table-case
30.

Table-case
30.

Gallery
VIII.

former are among the Bohemian and French Cystids, the last is well shown among the British fossils.

CLASS BLASTOIDEA.

Table-case
30.

The Blastoids (Bud-shaped) form a small class of Echinoderma, which arose at an early period, probably from Cystidea

Diploporita, and flourished chiefly in Devonian and Carboniferous times. The Museum possesses a rich collection, which served as basis of a monograph written by Etheridge and Carpenter and published by the Trustees. A list of the specimens has also been issued. Since the fossils are too small to be seen clearly, only a few characteristic examples are exhibited. The general appearance of the blastoid skeleton and the terms applied to its more obvious parts are shown in Fig. 30. The brachioles border five food-grooves, of which the skeleton is rather complicated. The contiguous edges of the plates termed deltoids and radials were folded, and in most of the genera these folds projected far into the interior of the theca and thus enabled the aerated sea-water to come close to all the

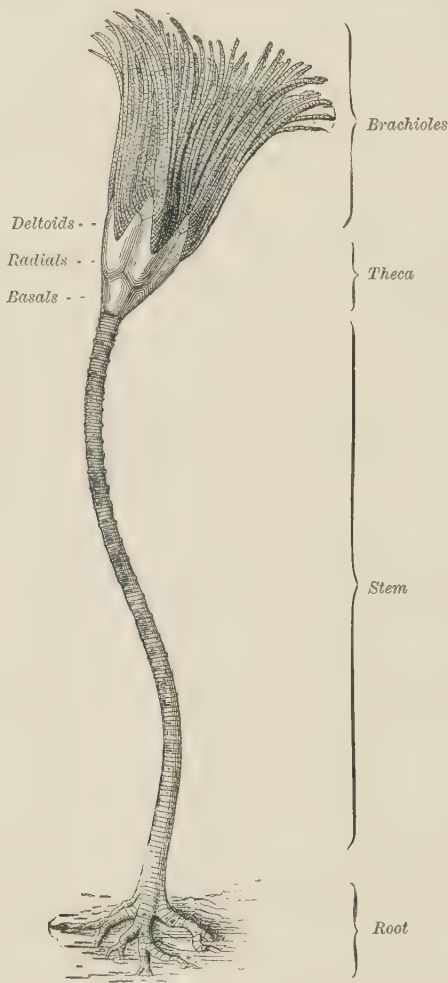


FIG. 30.—A typical Blastoid, *Orophocrinus fusiformis*, Carboniferous (Kinderhook) of Iowa, U.S.A.

Gallery
VIII.

Table-case
30.

internal organs; hence these folds are called hydrospires (water-breathers). In most blastoids the theca is borne on a stem and shows conspicuous five-rayed symmetry. In a few forms, however, the theca rested on the sea-floor, and this produced irregularity in its shape with a change in one of the food-grooves; examples of this are *Eleutheroerinus*, *Pentephyllum*, and *Zygocrinus*, which in other respects are dissimilar and not closely related.

The preceding Classes are essentially fixed forms, living with the mouth upwards and obtaining food by means of a current of sea-water swept towards the mouth along ciliated food-grooves. They are therefore termed **PELMATOZOA** (stalk animals) in opposition to the **ELEUTHEROZOA** (free-moving animals) such as star-fish and sea-urchins, which live with the mouth downwards and take more solid food into it without the help of ciliated grooves. In the Pelmatozoa hitherto discussed the food-grooves are supported on special structures usually stretched out from the body; and extensions from the hydraulic system may pass along these appendages, but do not penetrate the plated wall of the body (calyx or theca).

CLASS EDRIOASTEROIDEA.

We come now to a Class of Echinoderma, still living in the manner of Pelmatozoa, but with the food-grooves directly

Table-case
30.

floored by thecal plates and in some cases at least with pores between those flooring-plates, giving passage, it is supposed, to extensions from the hydraulic system. These are the Edrioasteroidea (sessile star-fish). Some of them, such as *Agelacrinus* and *Lepidodiscus*, were probably fixed for the whole of their existence, usually to some large shell. In these genera no pores have been found between the

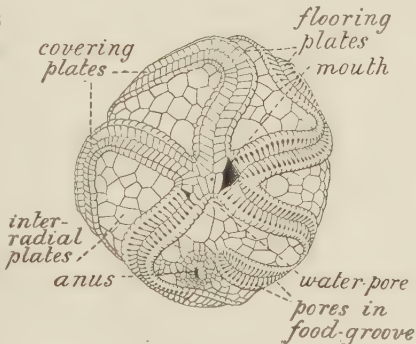


FIG. 31.—*Edrioaster Bigsbyi*. Seen from above. The covering-plates are removed from three rays, but remain on the other two. (After Bather.)

flooring-plates of the groove. Others, such as *Edrioaster* (Fig. 31) and *Dinocystis*, could probably shift their positions,

Gallery
VIII.

and in them pores are clearly seen. Pores, however, also occur in the food-grooves of a stalked form, *Steganoblastus*. The food-grooves of *Edrioaster* (Fig. 31) closely resemble those of a starfish, except that they, as well as the mouth, are protected by covering-plates like those of crinoids. It is possible that these curious forms may throw some light on the origin of starfish.

Since Edrioasteroidea are rare and of exceptional interest, both British and foreign examples are exhibited together in Table-case 30, and are supplemented by reproductions.

CLASS ASTEROIDEA.

On the further side of Table-case 30, the free-moving Echinoderms begin with the starfishes, generally regarded as constituting the simplest Class of Eleutherozoa. In a starfish the body is either markedly five-sided in outline or is more or less star-shaped, in which case it is said to consist of a central "disc" extended into "arms," which vary in number from 5 (e.g. the common cross-fish, *Asterias*) to over 40 (e.g. the sun-star, *Heliaster*); the mouth is in the centre of the body and is turned to the sea-floor; the anus is almost in the centre of the upper surface, but is absent in a few forms; the under side of the arms is grooved, and along each groove runs a vessel of the hydraulic system; this vessel gives off side-branches which end in free processes (podia) differing from those of *Pelmatozoa* in that each terminates in a sucker; between the flooring-plates of the groove are pores, through which pass branches from the podia, each communicating with a swelling (ampulla) within the body. This arrangement of the podia enables each one to be extended for locomotion, and to be withdrawn into the groove by the passage of the fluid from it into the ampulla; such an arrangement is found in no *Pelmatozoa* except perhaps some Edrioasteroidea; but from those forms starfish differ in having the groove unprotected by covering-plates. The remainder of the starfish skeleton consists usually of small plates or bars which serve to strengthen and support the stout but flexible skin.

Table-case
30.

The oldest **Palaeozoic starfishes** in the British collection are *Uranaster* and *Palaeaster*, represented by casts in Caradoc sandstone of Upper Ordovician age. From the Wenlock beds comes the heavily plated and many-armed *Lepidaster*. The Lower Ludlow shales of Leintwardine,

Herefordshire, have furnished a large number of starfishes belonging to the genera *Palasterina* (Fig. 32 b), *Sturtzaster*, *Rhopalocoma*, and *Bdellacoma*. Some obscure starfishes have been found in the Lower Devonian slates of Cornwall, but the fossils of this age are better studied in the beautiful series from Bundenbach in Prussia. In these the skeletons are altered into iron pyrites and imbedded in black slate, which has been cleaned away from them with most delicate care by Mr. B. Stürtz, the original describer of many of these specimens (see "Palaeontographica" 1886, 1890, and other papers mentioned on the labels). *Palaeasteriscus*, *Cheiropteraster*, and *Helianthaster* may be mentioned, but all are beautiful and interesting.

Gallery
VIII.

Upright
cases A2,
A3.

Returning to the British series, we find some good speci- Table-case
30.

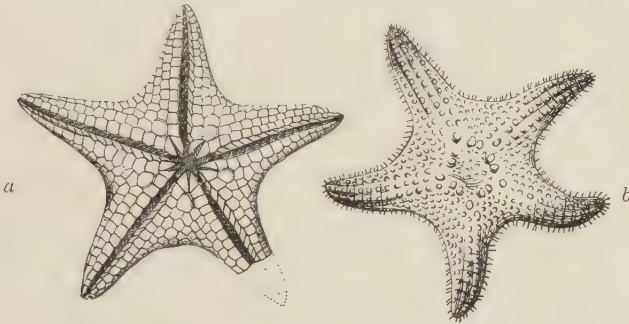


FIG. 32.—Palæozoic Starfishes. a, *Schuchertia stellata*, from the Ordovician of Ottawa; under surface with grooves and mouth. b, *Palasterina primæva*, Upper Silurian of Kendal; upper surface.

mens of **Jurassic star-fish**, notably *Tropidaster* from the Middle Lias, a massive *Pentagonaster Sharpi* from the Northampton Ironstone, a beautifully preserved *Asterias Gaveyi* and *Solaster Moretonis* from the Great Oolite. *Astropecten* is represented by species of various ages from Bajocian to Corallian, and some larger specimens of it are in Wall-case 17.

Cretaceous Asteroidea are best shown in the excellent series from the English Chalk, which have been described by W. P. Sladen and W. K. Spencer in a monograph of the Palaeontographical Society. Here the tessellated *Calliderma Smithi* and the fine group of *Pentaceros bulbiferus* are specially worth notice. Table-cases
30 & 29.

The **Tertiary star-fish** are represented chiefly by *Pentagonaster* and *Astropecten* from the London Clay, preserved in a pyrites that is regrettably liable to decompose. Table-case
29.

Gallery
VIII.Class **OPHIUROIDEA.**

The living Brittle-stars, Sand-stars and Basket-fish are separated from the star-fishes as a Class, because the arms are sharply marked off from the central disc, and have the grooves covered over by plates, and the flooring-plates of the grooves fused into a series of ossicles (little bones) like vertebrae, worked on one another by powerful muscles. Thus these arms can serve as limbs for locomotion; and the podia, not being needed for that purpose, usually serve only for respiration and touch. As a further result of this development, the arms no longer contain processes from the digestive and reproductive systems as they do in star-fish. In the Basket-fish the arms may branch, and are used for coiling round the stems of other animals or plants.

The **Palaeozoic Ophiuroids** do not show all these points of distinction from Asteroids; in many of them the arm-groove is not completely closed, and its flooring-plates are not yet fused into vertebrae. Species found in the Ordovician rocks of Bohemia are still more like Asteroids than any here exhibited. We begin with British Wenlockian forms, such as *Lapworthura* (Fig. 33) and *Protaster* from the Lower Ludlow shales. A slightly more advanced type is the little *Sympteryura* from the Lower Devonian of Cornwall. The Ophiuroids of this age, must, however, be studied in the Stürtz Collection from Bundenbach, where explanatory labels are given.

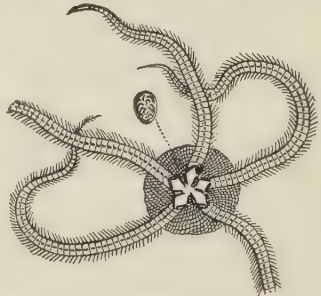


FIG. 33.—A Palaeozoic Ophiuroid, *Lapworthura Miltoni*. Lower Ludlow shales. Shows the mouth-frame in the centre of the round body. Between two of the rays is the madrepore, of which an enlarged figure is given.

Table-case
29.

Upright
case A3.

Table-case
29.

Wall-case
17A.

Among the British Wenlockian Ophiuroidea the most remarkable are *Eucludia* and its allies; for in them the arms do not extend beyond the disc, but to make up for this the few podia within the disc limits are of great size, and have a flexible armour of small plates.

From **Carboniferous to Trias** there are no British Ophiuroids, but on the lowest slope of Wall-case 17A may be seen *Onychaster*, from the Carboniferous rocks of Indiana,

with its coiled arms, a small *Hemiglypha* from the Muschelkalk, and a few other specimens.

Of **Jurassic Ophiuroids**, in the British Lias, the so-called Startish bed of Pliensbachian age, exposed between Charmouth and Bridport, has yielded *Ophioderma Egertoni* and other well-preserved brittle-stars. Interesting forms have lately been obtained from the Corallian Calcareous grit of Yorkshire. The Foreign Jurassic series consists mainly of some elegant little species from the Kimmeridgian lithographic stone of Solenhofen, belonging to the genera *Geocoma* and *Ophiurella*.

Another *Geocoma* comes from rather similar rocks of **Cretaceous** age in the Lebanon. From the English Chalk there are *Ophioglypha serrata* and other species recently described by Mr. Spencer in the monograph referred to above. By this time, it will be noticed, the genera have quite a modern aspect.

Ophioglypha Wetherelli, from the London Clay, is the most important of the British **Tertiary** sand-stars; there is also an *Ophiolepis* from Pleistocene deposits of the Clyde basin.

CLASS ECHINOIDEA.

Owing to their abundance, especially in Mesozoic and Cainozoic rocks, and to the continuous change in structure during geological time, the fossil Sea-urchins, or Echinoids, are of great value to the stratigraphical geologist and of no less interest to the student of evolution.

The differences between a sea-urchin and a starfish have sometimes been illustrated by imagining a starfish with short rays, and therefore with a five-sided or globular shape; then suppose the grooves to grow upwards to the neighbourhood of the anus so that they supplant all the leathery loose-plated skin, except a small area just round the anus; let this area be surrounded by five plates, each pierced by a pore for the passage of the generative products, and one of them also serving as madreporite—then one would have something very like a sea-urchin. But there is an obvious difference: in the starfish the radial water-vessel lies in a groove outside the skeleton; in the sea-urchin there is no groove, but a series of plates flush with the rest of the test, and the water-vessel lies beneath these—that is, within the skeleton—and the podia pass out through pores between or in those plates. Thus the test of a regular sea-urchin is

Gallery
VIII.

Table-case
29.

Wall-case
17A.

Wall-case
17A.
Table-case
29.

Table-cases
29, 28, 27.
Wall-cases
17A, 16, 15.

Gallery
VIII.

marked by five areas passing from near the anus to the mouth, and these areas are fringed by the podia so that they look like garden-paths or avenues (ambulacra). Thus it appears that the ambulacral plates, those that constitute these areas, are not the same structures as the flooring-plates of the groove in a star-fish. It would therefore in some respects be simpler to compare a sea-urchin with an *Edrioaster* in which the covering-plates of the food-grooves had become fixed, leaving passages for the podia, while the flooring-plates had gradually been absorbed; we must also suppose the *Edrioaster* to have turned upside-down, and its anus and water-pore to have moved to the surface now uppermost.

Table-case
29.

If now we examine the oldest British **Silurian Echinoidea**, namely, *Echinocystis* and *Palaeodiscus* from the Lower Ludlow shales, we shall observe that the anus has not yet reached the centre of the upper surface, that the ambulacra have not met regularly around either that centre or the anus, that in both genera the test was still flexible with its plates neither fixed in number nor regularly arranged, and that the pores for the podia are often between the ambulacral plates instead of surrounded by them as in later echinoids. Moreover, it has been maintained that some specimens of *Palaeodiscus* show traces of an inner set of plates corresponding to the flooring-plates of the groove in *Edrioaster*. These genera, however, had, as our specimens show, a well-formed jaw-apparatus of complicated structure, only a little simpler than that found in a Mesozoic *Cidaris* or in a recent *Echinus*. They must, therefore, have roved actively in search of food. The movable spines (radioles) borne by the plates are still small and not very different from those of some Asteroidea and Edrioasteroidea.

Wall-case
17A.

The **Devonian** rocks of Britain have yielded few remains of sea-urchins, but fossils from Germany (e.g. *Lepidocentrus*) show that, while the test remained flexible, the plates in each interradial area between the ambulacra were arranged in columns, and that often each plate bore one radiole larger than the others. In the British **Carboniferous** series are genera, such as *Palaeochinus* (Fig. 34, 1) and *Melonites*, that still have the interambulacral plates in many columns; but in *Archaeocidaris*, or *Echinocrinus*, these plates are relatively larger (Fig. 34, 2) and are definitely arranged in four columns. In other respects *Archaeocidaris* closely resembles the earlier forms of Cidaridae found in the Trias of the Tyrol

Table-case
29.

Wall-case
17A.

and Hungary. In these, as in the later Echinoidea, the interambulacra were restricted to two columns, but the test remained flexible.

The British **Mesozoic Echinoids** include many specimens described by T. Wright in his Monograph published by the Palaeontographical Society. With the **Jurassic** series we find the beginning of more familiar types. *Cidaris Edwardsi* from the Lias has the jaws preserved, and the radioles of various sizes still on the tubercles to which they were attached by muscles when the animal was alive. Here is also *Aerosolenia*, with specimens of the *A. pustulata*

Gallery
VIII.

Table-case
29.

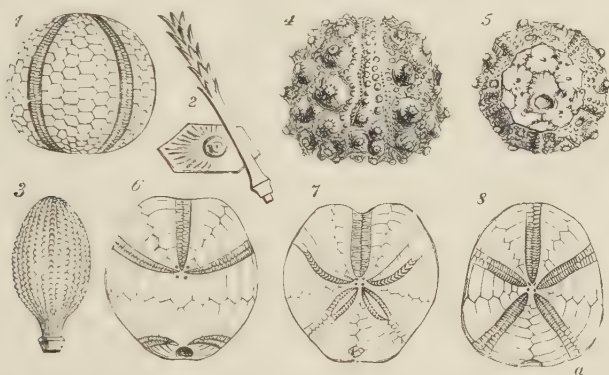


FIG. 34.—Types of Fossil Echinoidea. 1-5, Regular; 6-8, Irregular. 1, 2, Carboniferous; 3-5, Jurassic; 6-8, Cretaceous. 1, *Palaeochinus sphaericus*, side-view. 2, *Archæocidaris*, interambulacral plate and its radiole. 3, *Cidaris glandifera*, primary radiole. 4, *Hemicidaris intermedia*, side-view. 5, *Salenia petalifera*. 6, *Dysaster ringens*. 7, *Enalaster Greenovi*. 8, *Catopygus columbarius*. 5-8 are seen from above, with the anus towards the spectator. The figures are all somewhat less than natural size. (By permission of Messrs. A. & C. Black.)

that was found in crowds near Cirencester. The Jurassic fossils continue with the more modified *Hemicidaris* and *Pseudodiadema*. Then come early forms of *Diademina*, such as *Hemipedina* and *Diademopsis*, those from the Lias being but slightly removed from some of the Triassic species. They give rise, however, to more elaborate forms in the Oolitic rocks, e.g. the large *Hemipedina* (*Phymopedina*) *marchamensis*, with its numerous tubercles. An interesting allied type is *Pelanechinus*, in which the plates were widened and flexibly united. In this species have been found the little pincer-like appendages called pedicellariae, well known in living urchins, but rarely preserved on the fossils.

Table-case
28.

Gallery
VIII.

All the echinoids thus far mentioned have a circular outline, with the mouth in the centre of the under surface, and the anus at the other pole surrounded by an apical system of plates. Such echinoids are called **Regular**. In Bajocian time some urchins seem to have taken to moving generally in a single direction, and as one result the anus passed backwards from the apex, as may be seen in *Pygaster*. Then the mouth passed forwards, as in *Hyboclypeus*, and this resulted in modifications of the front ambulacrum and the hinder interambulacrum, e.g. *Collyrites*. At the same time in many forms the test became elongate, the jaws were lost, and the mouth developed instead a shovel-like lip, for the animal now took to burrowing through ooze and swallowing it on its way. Naturally the radioles became reduced to a coat of small, sometimes almost silky, spines. All such echinoids are called **Irregular**.

Table-case
28.

The foreign Jurassic echinoids are placed on the floor of Wall-case 16.

Wall-case
16.

The British **Cretaceous Echinoidea** contain two distinct faunas—one from the Lower Greensand, and one from the Gault, Upper Greensand, and Chalk. The former is small, but the latter is the most interesting in the British series. Its most striking feature is the predominance of large specimens of *Cidaris*, of which a fine series of specimens from the Chalk is shown. One may note especially the example [E. 1952] of *Cidaris sceptrifera* with the apical plates, and those of *Cidaris clavigera* [33,455 and 39,998] which show the jaws in position and the radioles attached. Following the Cidaridae come the Saleniidae, which have an additional plate in the apical system. The Diadematidae are represented by a large series of forms, of which *Cyphosoma Koenigi*, from the Chalk, is the best known. The genera *Glyphocyphus* and *Zeuglopleurus* are the forerunners of sea-urchins with pitted tests, such as *Temnopleurus*. The most interesting specimens are those of an *Echinothuria*, a genus with imbricating plates, carrying further the type of structure begun in *Pelanechinus* and brought to a high development in *Phormosoma*, *Asthenosoma*, and other genera now living in the abysses of the ocean.

Table-case
28.Table-case
27.

In the Irregular Echinoids of Cretaceous age the gradual change of form and ornament that takes place in all groups of fossils as they pass up through the rocks has of late received careful study. By these mutations geologists are able to recognise successive layers in the thick mass of

Chalk. Each of these layers is called a zone, and is given a name from some fossil characteristic of it, e.g. the zone of *Micraster coranguinum* (see the papers by A. W. Rowe in the Proceedings of the Geologists' Association, from 1900 onwards). In the exhibited series the specimens of each genus are labelled and arranged according to the zones from which they come. The species of *Micraster* and *Echinocorys* are particularly interesting in this respect. Other forms worthy of attention are *Discoidea*, of which one specimen [40,341] shows the internal processes that serve for the attachment of the jaw-muscles, here much modified; *Conulus* [*Galerites*], in which the jaws have been changed into buccal plates; the unique specimen of the curiously-shaped *Pygurus lampus* from the Upper Greensand of Lyme Regis; *Hagenovia* and *Infulaster*, which in their elongate shape approach the modern deep-sea genus *Pourtalesia*.

Gallery
VIII.

Table-case
27.

The foreign Cretaceous Echinoids are partly in Wall-case 16 and partly on the lowest slope of 15 c. A specimen of *Hemipneustes striato-radiatus* from Belgium, mounted on a block on the top shelf of 15 b, is the largest sea-urchin in the collection.

Wall-cases
16 and 15.

The British **Cainozoic Echinoidea** are fewer and smaller than those of the Mesozoic Era. The Eocene specimens particularly are dwarfed and stunted in comparison with those that lived in Southern France at the same time. The Pliocene specimens from the Crag of East Anglia are larger and more numerous. Among these *Tenuochinus Woodi* is represented by two forms, one of which has depressions at the upper ends of the interambulacra; these are supposed to have been for the reception and protection of the young, since several recent sea-urchins protect the brood in a somewhat similar manner. In addition to the ordinary North Atlantic forms, the Crag fauna contains various sea-urchins of West Indian type, such as *Rhynchopygus Woodi*, *Agassizia equipetala*, and *Echinolampas subrostrata*, and this implies a direct connection of warm shallow sea between the two regions.

Table-case
27.

The foreign Cainozoic Echinoids include a number of type-specimens from Malta and Australia. A series of the large *Clypeaster* from the Mediterranean basin and the West Indies is mounted on blocks on the top shelf. Two large specimens of *Chelonechinus*, a genus allied to *Cystechinus* which now lives in the ocean abysses, are of particular interest: one is from the radiolarian marls of Barbados, the

Wall-case
15.

Gallery
VIII.

other from the soap-stone of Fiji, and they have been held to prove that those rocks were raised from great depths since the Miocene Epoch.

CLASS HOLOTHURIOIDEA.

Table-case:
27.

The Sea-cucumbers, which form the last Class of Echinoderma, have no continuous skeleton, and are represented as fossils only by the spicules and minute plates deposited in the skin. These have been found so far back as in rocks of Carboniferous age. Spicules of *Cucumaria* from the Pliocene beds of St. Erth, Cornwall, and plates of *Psolus* from Scotch Glacial beds are exhibited.

Centre-
case.

An upright case in the middle of the Gallery contains a series of specimens intended to illustrate the importance of **ECHINODERMS as ROCK-FORMERS**. The back, or west side, of the case contains a single polished slab of Mountain Limestone full of stems and other fragments of Carboniferous crinoids. On the front of the case is a large slab of Silurian limestone from Gotland, with masses of crinoid stems showing on its weathered surface. Above this are samples of rock from various parts of the world, composed entirely or in great part of the skeletons of crinoids, of cystids, of blastoids, and of echinoids. The free-moving echinoderms, however, do not form so large a proportion of any rock as do the fixed forms. The latter often compose masses many feet in thickness and affording excellent building-stone.

The latest comprehensive account of Echinoderma, including fossil forms, is in Volume III. of "Treatise on Zoology," edited by E. Ray Lankester (London, 1900).

ANNELIDA.

Gallery
VIII.
East Side.

Among the numerous and diversely built forms of life that popular phraseology lumps together as worms, only the segmented or ringed worms have left in the rocks traces that can be identified by the palaeontologist. These worms constitute the group Annelida, and among them again it is only the Class **CHAETOPODA** (bristle-feet) and, with few exceptions, only one Order of that Class, namely the **Polychaeta** (many-bristles), with which we have to deal. These animals are nearly all marine, and at any rate have no representatives among freshwater fossils. They are all

soft-bodied animals, and the only portions capable of preservation in the rocks are the bristles, used for locomotion, and the horny jaws. The bristles of course can only be identified when connected with other traces of the animal. The jaws, some of which in the fossil state were long known as conodonts, are so minute that they can as a rule only be found by the washing and microscopical examination of the softer rocks. Evidence for the former existence of the free-moving forms, known as **Polychaeta Errantia**, may also be furnished by impressions, borings, trails, or worm-castings, the last-mentioned being the mud passed through the animal's body for the extraction of food and then excreted in coiled heaps (Fig. 37). These traces are somewhat unsatisfactory, and many have been vaguely assigned to "worms" which are now believed to have been formed by other animals, such as arthropods or molluscs. Though it may sometimes be convenient to give them names, it must be remembered that this implies no knowledge of the animal to which they may have been due. The most abundant fossils assigned to these Annelida are the hard tubes which the sedentary forms build up, sometimes from sand-grains stuck together, sometimes of carbonate of lime deposited in layers by the skin. These, however, show so little characteristic structure or even shape that it is difficult to be sure that they were always formed by animals related to the modern makers of similar tubes—the **Polychaeta Tubicola**. Moreover, since simple tubes are fashioned by some other kinds of animals, for example boring molluscs, one cannot even be certain that all these fossils are due to polychaetes. In spite of these difficulties, fossil "worms" have some interest for the geologist, since many of them are sufficiently distinct to enable him to identify stratigraphical horizons by their means, while others have left their remains in such quantity as to build relatively large masses of rock, and others again throw light on the conditions under which the rock wherein they occur was deposited.

The obscurest fossils of any that have been referred to Annelida are, as might be expected, also the oldest. They are, in fact, the oldest traces of life in the Museum, and come from rocks believed to be of **Pre-Cambrian** age at Loch Fyne in Argyll. Some large slabs presented by the eighth Duke of Argyll are in Wall-case 8 of Gallery XI.; smaller specimens are with the other British Annelida in the present Gallery. With these latter are other obscure fossils, named

Gallery
VIII.
Table-case
26.

Salterella and *Arenicolites* from the Basal Quartzites of **Lower Cambrian** age in Sutherland. All these are supposed to have been worm-burrows like those of the living lob-worm *Arenicola*, but they may equally well have been made by plant-roots. Some supposed tubes of *Serpulites* from the same Quartzites have a slightly better claim to an annelid origin. On the top shelf of the Wall-case is another *Arenicolites* from the **Upper Cambrian** of Wisconsin; in this the burrows are seen to stop short at the level of successive layers of rock, as though the animals had been killed off, either by a period of drought or by the sudden deposition of a thick coating of sand. With this compare the burrows in

Wall-case
15A.



FIG. 35.—The tubicolous polychaete *Ortonia*. *a*, *Ortonia intermedia*, from the Devonian of Canada; *b*, *O. conica*, adhering to a brachiopod shell, from the Ordovician (natural size); *c*, a single tube of the same, enlarged (after Nicholson).

Carboniferous sandstone from Calderwood Glen. A similar form called *Scolithus* comes from the Potsdam Sandstone of the same age near Ottawa; the bit of rock exhibited on the bottom slope of the Wall-case shows over 80 burrows on a surface no bigger than a man's hand.

Wall-case
15A.

Among British **Silurian** specimens may be noted the large *Serpulites longissimus*, of which a tube curved in an almost complete circle is at the back of the Wall-case, the small coiled *Spirorbis* (Fig. 36), and the ringed tubes of *Cornulites* often found in clusters. The similar tubes of *Ortonia* are attached to shells and such-like objects (Fig. 35). From the Lower Devonian of Cornwall come some peculiar

Table-case
26.

Wall-case
15A.

bodies called *Nereitopsis*, from a supposed resemblance to *Nereis*, one of the Errantia; some of these fossils, however, if not all, probably belonged to the Tubicola. The mass of tubes of *Serpula advena* from Caldy Island is of Upper Devonian age. Tubes referred to *Serpula* also come from the Carboniferous limestones of Ireland.

Spirorbis (Fig. 36) is frequently associated with plant-remains from the Coal Measures; but some of the fossils to which this name is given are probably mol-

lusc shells. The jaws and conodonts found in all these Palaeozoic rocks are too small for exhibition.

The **Jurassic** rocks contain many different shapes of tubes, referred to *Serpula* when adherent to other objects, to *Ditrypa* when free, and to *Galeolaria* when in dense clusters. Noteworthy examples of the first-mentioned are the tubes on a piece of jet from the Lias of Whitby, and those on the surface of a coral, *Thamnaustrea*, from the Coral Rag. Similar tubes are common in **Cretaceous** rocks; the Serpulite Limestone of Brunswick is formed of them. More interesting are the tubes formed of fish-scales, or fir-needles, or other objects, found in the English Chalk; the first-mentioned were originally described by Mantell as a fish—*Muraena lewesiensis*. One worm seems to have burrowed into sponges, and is found as an irregular spiral coil inside hollow flints. In the Wall-case the most interesting Mesozoic fossils are those from the Kimmeridgian of Solenhofen. Here is a *Eunicites* with bristles and jaws, and numerous coiled castings known as *Lumbricaria* (Fig. 37), and supposed to be those of worms, though once regarded by Agassiz as derived from the intestines of fish. *Pyrropolon* is a characteristically shaped tube, common at the top of the Cretaceous.

In the British **Tertiary** series, *Serpula heptagona*, from the Barton Beds, should be noticed, for the opercula which closed the tubes are preserved, and thus the genus can be more accurately determined. The coiled tubes known as *Vermetus bogneriensis*, of which two fine slabs are exhibited in the Wall-case, are thought by some to have been formed by a mollusc. A large block of *Serpula tenuis* comes from the



FIG. 36.—Supposed coiled tubes of Polychæta, from the Devonian of Canada. *a*, *Spirorbis omphalodes*; *b* and *c*, *Spirorbis arkonensis*. The smaller drawings give the natural size of the objects (after Nicholson).

Gallery VIII.
Table-case 26.

Table-case 26.

Wall-case; 15A.

Table-case 26.

Wall-case 15A.

Table-case 26.

Gallery
VIII.
Wall-case
15A.

Oligocene of the Isle of Wight. The *Eunice* found in a nodule of Pleistocene age from Greenland shows how well



FIG. 37.—A worm-casting from the Kimmeridgian Lithographic Stone near Solenhofen, *Lumbricaria colon*. This is a facsimile of the engraving in Baier's "Oryctographia Norica," supplement, plate VI., Fig. 6, published in 1757. The actual specimen, collected by J. J. Baier before his death in 1735, is on the middle slope of Wall-case 15A.

the Errantia can be preserved when circumstances are favourable. The rarity of such fossils proves once again the extreme imperfection of the geological record.

ARTHROPODA.

Gallery
VIII.
East Side.
Table-cases
25-20.
Wall-cases
14-12.

Next to the Annelida there are displayed the fossil remains of the Arthropoda, that great group of the animal kingdom which includes insects, centipedes, lobsters, barnacles, spiders, scorpions, and a host of less familiar forms. These animals have no internal skeleton, but the body is enclosed in a case made of a horny substance called chitin, which is not readily attacked by the ordinary acids or alkalis that percolate through the rocks. Sometimes lime salts are deposited in the chitinous envelope, and render it even more fit for preser-

vation. The case is not like a solid box, but is divided into a number of segments, separated as a rule by softer flexible skin. In primitive forms the whole body is divided into a series of generally similar segments, each bearing a pair of limbs; but in later forms several segments fuse more or less completely, especially at the head end of the body. The limbs also are segmented and their segments united by flexible joints, whence the name Arthropoda (jointed feet). A more striking feature, however, is that though, in their essential structures, all these limbs are organs of locomotion, some at the front end of the body, around the mouth, are used for seizing and biting food: the feet have become jaws. In most arthropods that live in the water some limbs behind the jaw-limbs have developed plates or plumes, which serve as gills. Land arthropods breathe either by small lung-sacks or by long tubes called tracheae, which open to the air by holes, called stigmata, in the sides of the body-segments.

The great majority of arthropods now living are divided into the following Classes: Insecta, including flies, butterflies, beetles, and bugs; Chilopoda or centipedes; Diplopoda or millipedes; Crustacea, including crabs, lobsters, sand-hoppers, wood-lice, barnacles, and water-fleas; and Arachnida, including spiders, ticks, and scorpions. All these Classes are represented by numerous fossils back to Palaeozoic times; but many fossil arthropods are not obvious members of any of these Classes. Such are the trilobites, the Eurypterida (*Eurypterus*, *Pterygotus*, &c.), and the king-crabs, which last have persisted to our own day. Certain resemblances between these forms have led some writers to unite them in a single Class. It is now generally admitted that the king-crabs and Eurypterida are related to the Arachnida; but they may still be conveniently distinguished as Merostomata. The trilobites were perhaps allied to the Merostomata, and yet there are some features in which they resemble Crustacea. It may therefore be as legitimate as it is convenient to keep them apart as a Class Trilobita. These Classes will now be considered in the order in which the British specimens are arranged in the Table-cases, namely: Trilobita (Cases 25, 24); Arachnida (Cases 24, 23); Crustacea (Cases 23-20); Diplopoda, Chilopoda, and Insecta (Case 20). Setting aside the centipedes and millipedes, this order may be justified as that in which the Classes successively became dominant during geological time.

CLASS TRILOBITA.

Gallery
VIII.
Table-case
25.

The structure of the Trilobites (three-lobed forms) is illustrated by models. *Dalmanites caudatus* (Fig. 38) shows

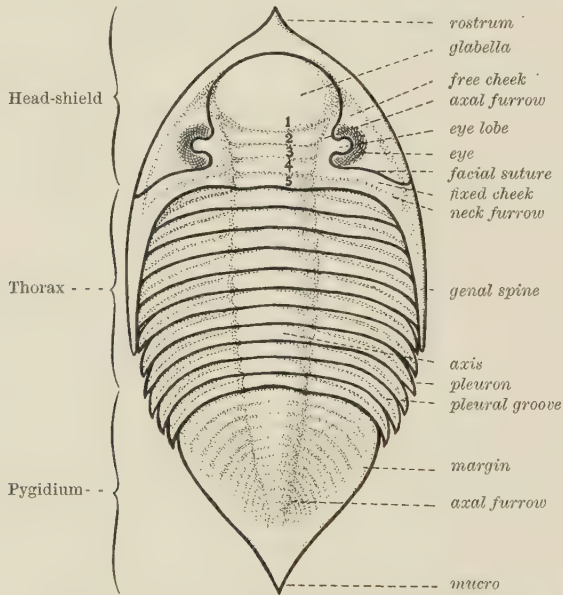


FIG. 38.—Diagram of a Trilobite, *Dalmanites* [*Phacops*] *caudatus*, Wenlockian. Where the black lines are drawn across is a definite suture or joint. The five segments of the head-shield are numbered.

the ordinary view, namely, the back or upper side of the horny coat. Two grooves running lengthwise divide it into three lobes—a middle or “axial,” and two side or “pleural” lobes. The principal organs of the body lie within the axial lobe, while the pleural lobes are expansions of this for the protection of the limbs. At first glance the coat appears made of several (about thirty) segments, gradually decreasing in size and importance from head to tail. Inspection shows, however, that these segments are more closely united into three regions: the head-shield, composed of five segments; the thorax, of eleven segments; and the tail-shield or pygidium, of about fourteen segments. The segments of the

head-shield are the most closely united, and are of the same number in all trilobites. Those of the thorax are flexibly joined, and in other genera vary from two to twenty-nine. The pygidial segments, which also vary much in number, are fused into a single shield, from which all traces of the original segmentation has sometimes disappeared. The axial portion of the head-shield, called the glabella, is separated by the dorsal or axial furrows from the pleural portions or cheeks, and is divided by side-furrows into lobes representing the five primitive segments. The part of each cheek next the glabella is firmly attached to it or "fixed." From this the rest of the cheek is separated by the "facial suture," and is "free." The free cheeks, which in many genera are separate, here meet and fuse in front of the glabella. They bear the compound eyes, which stand up like semi-circular towers bearing facets on their outer walls. In many trilobites the eyes are not so conspicuous, and in some they seem to have been altogether absent. The hinder corners of the head-shield, called the genal angles, are here produced into spines. These are part of the fixed cheeks; but in some trilobites, where the free cheeks take a larger share in the head-shield, they are part of those cheeks. Each segment of the thorax consists of an axis and two pleura. The axis stretches forward beneath the axis of the segment in front, forming an articular surface. Each pleuron has a groove running obliquely from front to back and connected with the occasional overlap of the pleuron in front as the animal moved. Not all trilobites have the pleura grooved, but some have them also bevelled at the front corners, forming facets on which the hinder angles of the pleura in front could play; for these trilobites could roll up like a wood-louse. The pygidium is jointed on to the last thoracic segment; its shield has a smooth border, produced into a spine.

The under side of the trilobite, with its appendages, has been made known chiefly by the labours of C. D. Walcott and C. E. Beecher. A restoration of *Triarthrus*, a genus of the family Olenidae, is exhibited (Fig. 39). The edge of the carapace is turned over on the under side and supports a thin membrane, in which are the two openings of the digestive tract: the mouth, beneath the glabella, and the anus, beneath the pygidial axis. In front of the mouth is the hypostoma or fore-lip, behind it is the metastoma or hind-lip. Specimens of other species showing these structures are exhibited. Every body-segment, except that in which

Gallery
VIII.
Table-case
25.

the anus opens, bears a pair of appendages, attached to transverse thickenings of the ventral membrane. The front pair form whip-like antennae. The remaining pairs are branched, one branch being a crawling leg, the other branch bearing a fringe of bristles or of lamellae. The basal segments of the four pairs on the head served to bite food and to pass it into the mouth. The lamellate branches of the remaining limbs may have served partly for swimming, partly for breathing.

Trilobites lived only in the sea, some on reefs, some on muddy or sandy bottoms; some, it is inferred either from the absence or the extraordinary size of the eyes, in deep

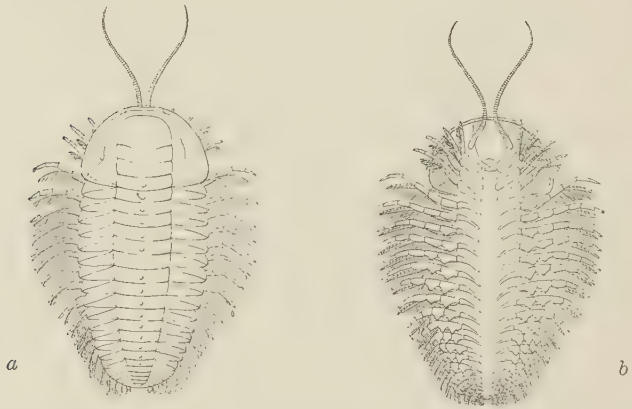


FIG. 39.—Reconstruction of a Trilobite, *Triarthrus Becki*, from the Ordovician, Utica Slate of New York; *a*, upper side; *b*, under side; slightly enlarged. (After Beecher. Table-case 25.)

water. In the growth of an individual trilobite of simple structure, the free cheeks and the eyes borne by them are at first not seen on the upper surface of the head-shield. As the animal grows they appear at the edge, and gradually come to occupy more and more of the upper surface. Some early trilobites, however, such as *Agnostus* (Fig. 40 *a*), *Harpes*, and *Trinucleus*, never reach this stage, and may be separated as a Grade **Hypoparia** (under-cheeks) from those in which the free cheeks are visible on the upper surface. In these latter the free cheeks may be confined to the forepart of the shield, as in *Calymmene*, *Staurocephalus* (Fig. 40 *c*), and *Phacops* (Fig. 38), or they may stretch right back so as

Table-case
25.

to include the genal angles, as in *Olenus* (Fig. 40 *b*), *Paradoxides*, *Triarthrus* (Fig. 39), *Oyggia*, *Bronteus*, and *Acidaspis*. Trilobites with the latter character are called **Opisthoparia**

Gallery
VIII.
Table-case,
24.
Table-case
25.

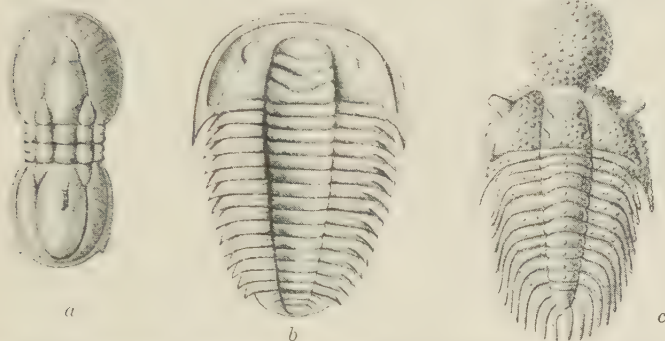


FIG. 40.—Examples of Trilobites. *a*, Hypoparia, *Agnostus princeps*, Olenidian Age; enlarged $2\frac{1}{2}$ times. *b*, Opisthoparia, *Olenus cataractes*, Olenidian Age. *c*, Proparia, *Staurocephalus Murchisoni*, Wenlockian Age.

(back-cheeks), while those with the free cheeks in front only are called **Proparia** (front-cheeks).

Trilobites are found well developed in the oldest Cambrian rocks, being represented by Hypoparia, which soon die out, and by Opisthoparia. Three genera of the Opisthoparian Family Olenidae, *Olenellus*, *Paradoxides*, and *Olenus*, have given their names to the Lower, Middle, and Upper Cambrian Ages. With the Ordovician arise the Proparia, and the Trilobita as a whole attain their acme. Through Silurian and Devonian times they gradually decline in numbers and size, till in the Carboniferous only a single family remains, of which one genus, *Phillipsia*, struggles on to the Permian.

The **British trilobites** are allied to those of Scandinavia and Russia, rather than to those of Bohemia and the rest of Europe and eastern North America. They have been described mainly by J. W. Salter and H. Woodward in the Monographs of the Palaeontographical Society, and many specimens there figured are in the national collection. The large *Paradoxides* from the Middle Cambrian of St. Davids will attract notice. *Angelina Sedgwicki* from the Tremadoc Slates is the usual text-book instance of how fossils may be distorted by earth-movements. The Lower Cambrian Sandstone of Comley, Shropshire, has yielded frag-

Table-case
25.

Wall-case
14B.

Table-case
24.

Wall-case
14A.

Table-cases
25, 24.

Gallery
VIII.
Table-cases
25 & 24.

ments referred to the wide-spread genus *Olenellus* and other genera. *Trinuclaus*, with ornamented head-shield, is a characteristic Ordovician genus. *Asaphus tyrannus* and *Ogygia Buchi* are common in the Llandeilo Flags of the same Epoch. *Illaenus*, with smooth head-shield and pygidium, has even lost the axial furrows from the thorax, and forms a strong contrast to the spiny *Acidaspis* or the tuberculate *Encrinurus* of Wenlockian age. *Calymmene Blumenbachi* is "the Dudley Trilobite," and to its coiled individuals is due the name of the genus ("covered up"). *Homalonotus* is another form devoid of ornament and losing its furrows. In *Sphaerexochus*, *Deiphon*, and *Staurocephalus* (Fig. 40 c), the swollen glabella is a remarkable feature. Among Devonian trilobites note the fan-shaped pygidia of *Bronteus* and the tripartite head of *Trimerocephalus*. The three Carboniferous genera *Griffithides*, *Phillipsia*, and *Brachymetopus* are well represented.

Between
Wall-cases
14 & 15.
Wall-case
14.

In the **foreign collection** one may notice slabs from the Cambrian of China covered with "petrified swallows," as the Chinese call these remains of *Stephanocare*, *Drepanura*, and *Agnostus* (Plate V). Here are fragments and a restoration of the huge *Asaphus megistos* from the Ordovician of Ohio. The Bohemian collection obtained from J. Barrande is particularly valuable. Among the Cambrian genera one should note *Ptychoparia* and *Sao*; among the Ordovician, *Olenus* (Fig. 40 b), *Isotelus*, the large-eyed *Aeglina*, the deeply incised pygidia of *Areia*, and *Calymmene Tristani* which marks a horizon of Llandeilian age. *Calymmene senaria* is the species in which Walcott discovered the appendages by means of cross-sections. Of Silurian genera, *Proëtus*, *Arctusina*, and *Harpes*, from Bohemia, should be noticed. The Devonian series includes large pygidia of *Bronteus* from Bohemia, and several trilobites from South Africa.

CLASS ARACHNIDA.

Table-cases
24 & 23.
Wall-cases
13 & 14,
& adjoining
pillars.

In this Class, as already explained, we include the **MEROSTOMATA**. First in this division comes the Order **Eurypterida**, whose structure may best be studied in the exhibited model of *Eurypterus* (Fig. 41) as well as in the large specimens of *Pterygotus*, *Skimonia*, and *Stylonurus*. The segmented body is long, flattened, and divided into three regions. The front one consists of the head and some (? 6)



CAMBRIAN TRILOBITES FROM CHINA.

[To face p. 86.

body-segments fused under a single shield. On its upper surface is a pair of small simple eyes (ocelli) near the centre, while a pair of compound, faceted eyes is placed on or near

Gallery VIII.
Between Wall-cases 12, 13 & 14.

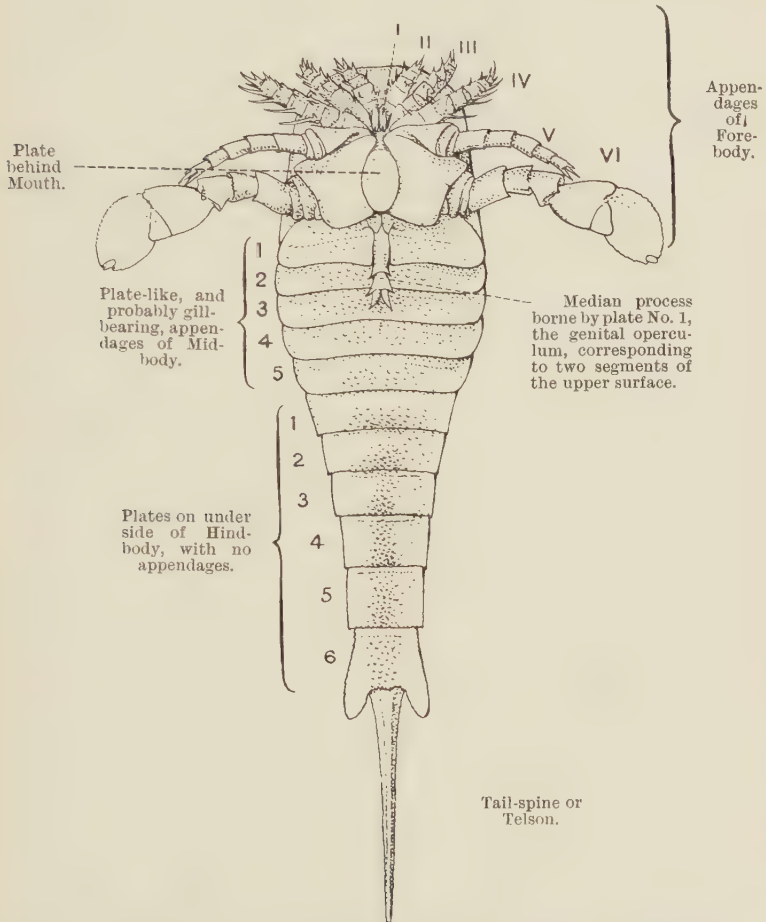


FIG. 41.—Under surface of *Eurypterus Fischeri*, from the Silurian of Oesel. (Nat. size, after the model made for the Museum, based mainly on the work of G. Holm.)

the front margin. On its under surface is the mouth, with a plate in front of it and another behind it, as in the trilobites. In front of the mouth is a pair of limbs (1), differing greatly

Gallery
VIII.

in size in different genera, but always ending in pincers (chelae). At the sides of and behind the mouth are five pairs of limbs (II-VI), variously modified in different genera for crawling, swimming, or grasping, but always agreeing in having the basal segment toothed to serve as a jaw, and those of the hindmost pair much larger than the others. On the under surface of the first (or second) segment of the mid-body are the openings of the reproductive glands, covered by a paired plate with a median process, the whole known as the genital operculum. The four following segments bear each a somewhat similar plate, to which were probably attached leaf-like gills. The segments of the hind-body have no appendages, except the telson. The surface of the chitinous envelope usually bears a scale-like ornament. The Eurypterida are first known from Cambrian rocks, and attained their maximum in both numbers and size about the beginning of the Devonian Epoch, when they seem to have frequented shallow waters and lagoons; they are found in the Coal Measures in circumstances indicating a brackish or freshwater habitat; the last survivor is associated with land-plants of Permian age. The British fossils belong chiefly to the genera *Eurypterus*, *Slimonia*, and *Pterygotus*. The remains of the last-mentioned, from the Old Red Sandstone of Scotland, are large and conspicuous objects, widely known through the writings of Hugh Miller. In the Silurian rocks of Oesel in the Baltic smaller species of *Eurypterus* (Fig. 41) and *Pterygotus* occur in a beautiful state of preservation. The great *Stylonurus* and the smaller *Hughmilleria* lived in the Devonian seas of North America.

Table-case
23.
Wall-case
13c.

Next come fossils of the Order **Xiphosura** (sword-tails), of which *Limulus*, the king-crab, is the living representative (Fig. 42). Here the fore-body is proportionately much larger, and covered by a domed shield of horse-shoe outline. Near its middle line are the ocelli, and further back on each side, about halfway from the margin, is a compound eye. The mid- and hind-bodies are, in *Limulus*, covered by a single shield, with six spines at each side and with grooves on its back indicating that it is composed of certainly six segments and probably more. This is separated from the front shield by a strongly marked flexible articulation, and the bayonet-shaped telson is jointed to it behind. The under-surface of the fore-part has a central mouth surrounded by appendages, which scarcely differ from those of Eurypterida beyond the removal of the sixth pair from

a share in biting the food. The six segments of the hind-part carry paired plate-like appendages, as in Eurypterida, the first forming the genital operculum, the rest bearing gills on their hinder surfaces. *Limulus* then differs from the Eurypterida mainly in the fusion and reduction of the abdominal segments. In the very young *Limulus*, however, there are nine such segments, not yet fused, and there are among the older fossils of this Order many that show a similar or greater approach to the Eurypterid plan. The first of these exhibited is the Silurian *Neolimulus*, with at least nine free segments; then *Hemiaspis*, in which the last three are narrower than the others and are followed by the telson. *Belinurus* from the Coal Measures has eight abdominal segments, of which the last two or three are fused; while in the contemporaneous *Euproöps* [*Prestwichia*] the segments are reduced to seven, and these are fused. If the Coal Measure fossils known as *Cyclus* are not larval stages of the contemporaneous Xiphosura, one can only say that they are just what one would expect those larvae to have been. The resemblance of all these early Xiphosura to trilobites is also too striking to be overlooked. *Limulus* itself first appears in the Trias; several specimens from the Solenhofen stone of Kimmeridgian age are shown.

Gallery VIII.

Table-case 23.

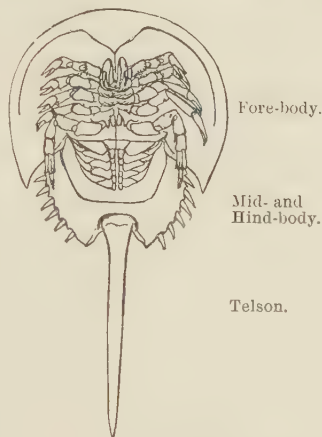


FIG. 42.—Under surface modern Xiphosure, *Limulus polyphemus*, the King-crab. About $\frac{1}{10}$ th the diameter of the real animal.

Wall-case 13c.

As the Eurypterida were assuming a fresh-water existence before vanishing, the Order **Scorpionida** was making its appearance, being first represented in the Silurian rocks by what seems to have been an aquatic, if not actually a marine form. This is *Palaeophonus* (Fig. 43), found in both Scotland and Gotland. It consists of the same number of segments, arranged in the same way as those of Eurypterida, and bearing similar appendages. The first two pairs of these have strong pincer-claws, the next four pairs are stout and end in a single claw, whereas in later scorpions they are

Gallery
VIII.

thin and end in a double claw. The genital operculum is on the seventh segment, and on the eighth the appendages have been modified into a pair of organs corresponding to those which in later scorpions have a toothed edge and are known as pectines (combs). It is possible that the breathing organs on segments nine to twelve remained as in the

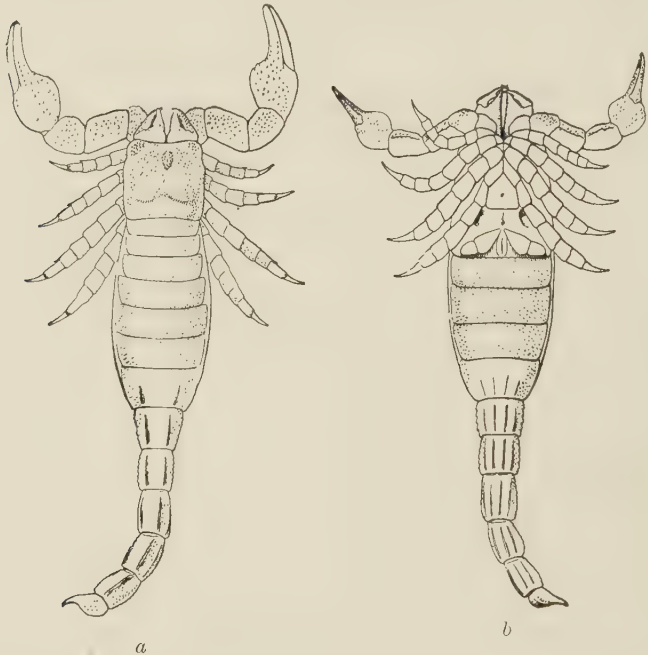


FIG. 43.—Silurian primitive Scorpions, *Palæophonus*. *a*, *P. nuntius*, Ludlovian of Gotland, upper surface. $\frac{4}{3}$ nat. size. (R. I. Pocock, after Thorell & Lindström.) *b*, *P. caledonicus* [*Hunteri*], Ludlovian of Lanarkshire, under surface, about twice nat. size. (R. I. Pocock.) (Both blocks lent by Messrs. Constable, from Lankester's "Extinct Animals.")

Eurypterida. But in many scorpions of Carboniferous age an important change has taken place in that the covering plates have closed over the lamellae of the gills, leaving only slit-like openings called stigmata. Thus when the animal emerged from the water the lamellae remained moist, and breathing took place by the admission of air to them through the stigmata. They are no longer gills, but lungs. Specimens from England, and a fine scorpion from Bohemia called

Cylophthalmus are exhibited. Later scorpions differ in no important respects from those of the Carboniferous Epoch.

Adjoining the British fossil scorpions are some other Carboniferous Arachnida, mostly found on splitting open nodular concretions of ironstone that occur in the Coal Measures of Staffordshire and Lancashire. The most interesting genera are *Anthracosiro* and *Eophrynus* (Fig. 44), which

Gallery
VIII.
Table-case
23.

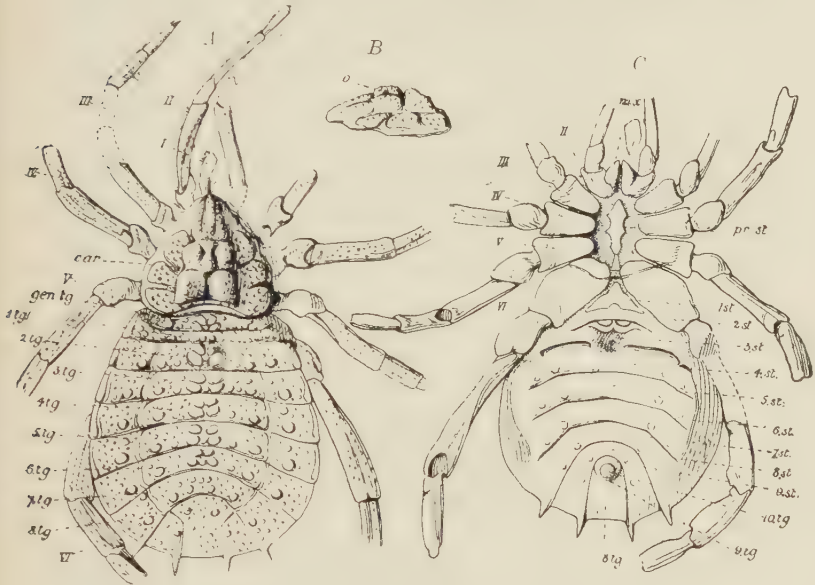


FIG. 44.—An example of the Anthracomarti, *Eophrynus Prestvicii*, from the Coal Measures of Dudley. A, upper surface; B, side view of front shield, the front end being to the left; C, under surface. I—VI, appendages of the fore-body, the base of II bearing a biting process, *mx*; *car*, front shield with eye-pit, *o*; *pr. st.*, sternal plates on its under surface; the upper (tergal) and under (sternal) segments of the hind-body are lettered 1—10*tg* and 1—9*st* respectively, that lettered *gen. tg* in A corresponds to the generative openings on the under side. Enlarged about 2 diameters. (From R. I. Pocock, *Geological Magazine*, 1902, and *Palaeontographical Society's Monographs*, 1911. Table-case 23.)

belong to a group called **Anthracomarti**, apparently ancestral to the recent Pedipalpi (whip-scorpions and allies) and Opiliones or harvest-spiders, and in some respects intermediate between them. The hind-part of the body is still articulated to the fore-part, and consists of flexibly joined segments. As in typical Arachnida the mouth is at the front of the body, and only the first two pairs of limbs take

Gallery
VIII.

Wall-case
13c.

part in biting; the four other pairs are solely for walking. The breathing organs were probably lung-books, as in Scorpions and Opiliones, but there is still little evidence on this point. The **Araneae** or true spiders are also found among Carboniferous fossils; some from Bohemia are shown. These and other orders of Arachnida are, however, not very richly represented in the rocks until Cainozoic times, when they are met with in the Oligocene of the Isle of Wight and of Florissant in Colorado, in the lignites of Rott near Bonn, the Miocene of Oeningen in Baden, and in the Baltic amber.

CLASS CRUSTACEA.

Table-cases
23-20.
Wall-cases
13 & 12.

These are almost all dwellers in water, breathing by gills. Their outer chitinous envelope is more often thickened by lime than is the case in the Classes previously described, and this crustaceous nature combines with their habitat to render them fairly common fossils. The annexed figure of a fossil lobster (Fig. 45) shows that in the more typical forms the

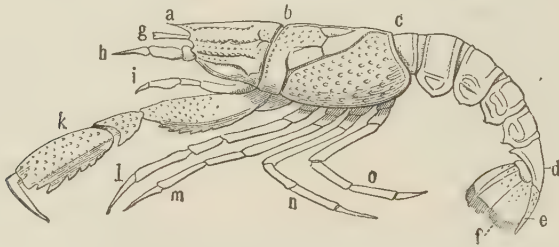


FIG. 45.—A typical Crustacean; one of the Macrurous Decapods, *Glyphea regleyana*, of Oxfordian age. *a-b*, head; *b-c*, thorax, covered by the carapace; *c-d*, abdomen, bearing a telson, *e*, and tail-fins, *f*; *g*, eye; *h, i*, limbs of the head; *k-o*, walking limbs. Two-thirds nat. size. (From Woods' "Paleontology," by permission of the Cambridge University Press.)

envelope is composed of segments, in which an upper and under half are clearly distinguished. Several front segments are joined together and covered by a shield, part of which projects backwards as a carapace, and from the number of limbs borne by this part of the body the number of segments may be estimated; in the lobster, for instance, it is thirteen (not all preserved in the fossil figured). The six remaining segments form the abdomen, at the end of which is the telson. In the number of the body-segments, in the manner

in which they are united, in the limbs which they bear, and in the extent to which some of them are covered by a carapace, the Crustacea manifest much diversity. They may be divided into five Sub-Classes: Branchiopoda, Ostracoda, Copepoda, Cirripedia, Malacostraca.

The **BRANCHIOPODA** (gill-feet) are represented among fossils by only one Order, the **Phyllopoda** (leaf-feet), which owe their name to their numerous leaf-shaped gill-bearing limbs. In the large number of body-segments and the uniform nature of the limbs, as well as in some points of internal structure, modern phyllopods are considered to approach the supposed ancestors of Crustacea. The carapace may be absent, as in *Branchipus*, or may form a large shield over the fore-part of the body, as in the living *Apus*, or may be folded down the middle line, and the two halves held together by a muscle crossing them inside, as in the little *Estheria*. All recent phyllopods are essentially inhabitants of fresh water, but since they survive the change of this into salt water and even brine, as in the Great Salt Lake, their presence in any rock does not necessarily imply its fresh-water origin. *Protocaris* from the Cambrian of Georgia resembles *Apus*, and the doubtful *Anomalocaris* from the Cambrian of British Columbia has been compared to the abdomen of *Branchipus*. In Devonian shales *Estheria* and its relatives are common fossils. In Triassic and a few later rocks *Apus* is met with, and from the Oligocene of the Isle of Wight there is a *Branchipodites*, here exhibited.

The **OSTRACODA** (Fig. 46, 5) resemble *Estheria* in having a carapace of two valves united along the back by a membrane, and capable of being tightly closed by an internal muscle. The appendages, which differ from those of the Phyllopoda, can be thrust out between the lower edges of the valves, and used for creeping or swimming. Appearing already in Cambrian times, the Ostracoda rapidly became numerous in both individuals and species, and still abound in the seas and lakes of to-day. They live usually in shallow water, and occur in such crowds that their remains sometimes form considerable beds of rock. *Leperditia*, *Beyrichia*, *Thlipsura*, *Eutomis*, and the four families which they represent, are all Palaeozoic. *Cytherella*, *Cypridina*, and the relatives of *Cypris*, range from Ordovician to modern times. *Cythere* and its family are Mesozoic to Recent. Most ostracods are too small for satisfactory exhibition, so that only a small selected series is shown.

Gallery
VIII.

Wall-case
13c.

Table-case
23.

Table-case
23.

Wall-case
13c.

Gallery
VIII.
Table-case
22.
Wall-case
13B, c.

The **CIRRIPIEDIA**, or barnacles and their allies, are of special interest to British naturalists as having formed the subject of two monographs, on the recent and fossil forms respectively, by Charles Darwin. They have a wider interest as representatives of a free and actively moving group of animals that, so soon as their early wandering days are over, settle down to a fixed existence, becoming permanently attached by the forepart of the head to rocks, shells, drift-wood, ships, and the like. Some, as the common

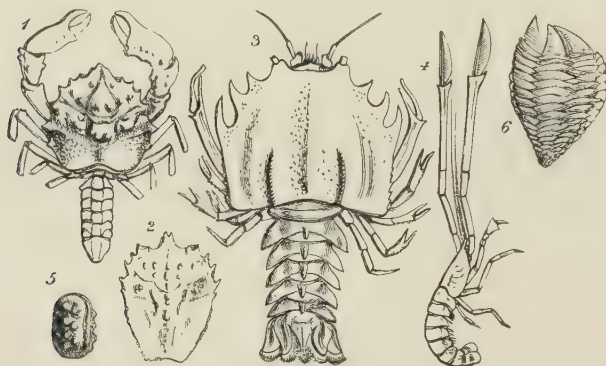


FIG. 46.—Fossil Crustacea. 1, a Brachyuran Decapod of the tribe Dromiacea, *Dromilites Lamarcki*, London Clay. 2, a Brachyuran Decapod of the tribe Oxystomata, *Palæocorystes Stokesi*, Gault and Upper Greensand. 3, a Macruran Decapod of the tribe Eryonidea, *Eryon arctiformis*, Solenhofen Stone. 4, a Macruran Decapod of the tribe Loricata, *Mecochirus longimanus*, Solenhofen Stone. 5, an Ostracod, *Cypridea tuberculata*, Wealden. 6, a Cirripede, *Loricula pulchella*, Turonian Chalk; the specimen was figured by C. Darwin. All figures except 5 and 6 are considerably less than natural size.

Balani or acorn-shells of our coasts, are closely and immediately attached to the rock or wood; others, as the barnacles, hang from a long stalk. In either case they develop a calcified shell composed of a number of definite pieces. Six pairs of feathery cirrus-like limbs, to which the Sub-Class owes its name, stretch out from the shell, and continuously sweep food-particles to the mouth within the shell. In the Ordovician, Silurian, and Devonian rocks occur fossils like tubes of overlapping scales, supposed to have been the plated covering of primitive cirripedes in which the main shell or capitulum was not yet distinguished from the covering of the stalk; such are *Lepidocoleus*, with two

columns of scales, and *Turrilepas*, with from four to six columns. In the Jurassic *Archacolepas* and the Cretaceous *Loricula* (Fig. 46, 6) the plates of the capitulum are distinguishable, but are not so fully developed as in *Pollicipes* and *Scalpellum*, which, first found in Jurassic and Lower Cretaceous rocks respectively, continue to our own day. The Pliocene Crags of East Anglia furnish many Balanidae, essentially a Tertiary family, though some Devonian fossils from North America have been referred to it.

The rest of the fossil Crustacea belong to the Sub-Class **MALACOSTRACA** (soft shells), an old name originally intended to distinguish these "shell-fish" from those with hard calcareous shells. There are nineteen (or twenty) body-segments, of which eight form the thorax, and six (or seven) form the abdomen. Most of the larger and better known modern Crustacea fall within this Sub-Class. Into the unsettled question of their classification we shall not here enter, but merely allude to those Orders or other groups that are represented by fossils. First comes the group **Phyllocarida**, in which are doubtfully but conveniently placed a number of Palaeozoic Crustacea, which may or may not be related to the recent *Nebalia*. These have over the head and thorax a large shield, which may be folded as in the Phyllopoda, and may bear a narrow beak-like plate loosely joined to it in front. The abdomen consists of ring-like segments (seven in modern forms), and the telson has side-spines. In *Hymenocaris*, from the Cambrian rocks of Wales, the shield is in one piece. In *Caryocaris* from the same rocks it is bivalve, as also in the Ordovician and Silurian *Ceratiocaris*, which was sometimes two feet long, and in the Devonian genera, *Echinocaris* from North America and *Aristozoë* from Bohemia. In *Rhinocaris*, from the Devonian of New York, a third plate arose in the middle of the back between the two valves. *Discinocaris* and allied forms, ranging from Ordovician to Trias, had an almost circular divided shield, much like the brachiopod shell *Discina*, while *Aptychopsis* and others have been confused with the similarly shaped opercula of ammonites (compare Fig. 83).

There have long been known from Carboniferous and Permian rocks some genera differing greatly from their contemporaries and placed in a division **Syncarida**. These are now considered to resemble and to be related to a remarkable Crustacean called *Anaspides*, which lives in fresh-water pools near the top of Mt. Wellington, Tasmania.

Gallery
VIII.

Table-case
22.

Wall-case
13 B, C.

Table-case
22.

Wall-case
13B.

Gallery
VIII.Table-case
22.
Wall-case
13B.

This animal has the segments of the thorax all distinct, covered by no carapace, and bearing limbs with swimming branches and plate-like gills; its eyes are stalked as those of a lobster. Among British fossils the Syncarida are represented only by poor specimens of *Palaeocaris*, also found in the Coal Measures of Illinois. To show the characters more plainly, a specimen of *Uronectes* [*Gampsonyx*] from the Lower Permian of Saarbrücken, Germany, has been placed in the Table-case.

Table-case
22.

Several Crustaceans now referred to independent Orders of Malacostraca were till recently united under the name **Schizopoda** (cleft-feet). Since certain fossils are too obscure to be referred with certainty to any other position, the division Schizopoda is provisionally retained for them in the exhibited series. Most are from the Coal Measures. *Palaeocrangon* and *Anthropalaemon* outwardly resemble the Decapoda, but appear to have some thoracic segments still unfused with the carapace. *Pygocephalus*, with its brood-pouch, may be an ancestor of *Mysis*, the modern "opossum shrimp."

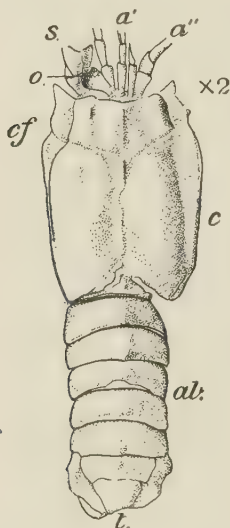


FIG. 47. — *Anthropalaemon Woodwardi*, Lower Coal Measures, Lancashire. *a'*, antennule; *a''*, antenna; *o*, stalked eye; *cf*, furrow separating head-shield from carapace, *c*; *ab*, abdomen; *t*, telson. Enlarged 2 diam. (From H. Woodward, "Geol. Mag.," 1905.)

Table-case
22.
Wall-case
13B.

of Devonian age, but their isopod nature may be questioned. *Cyclospiraeroma*, however, from the Jurassic rocks of Northampton and Solenhofen, is an undoubted

Next come fossils referred without doubt to the clearly defined Order **Iso-poda**. Of this Order the most familiar representative is the wood-louse, but most isopods are marine and some inhabit fresh water. The flattened body has a small head-shield (not a carapace) to which are flexibly joined seven thoracic segments, bearing each a pair of walking legs; plates attached to the bases of these limbs form a brood-pouch for eggs and young; the abdomen, which bears gill-plates, is reduced in size, its segments partially fused, with a relatively large tail-shield. *Oxyuropoda* from Kiltoran and fragments of a large *Prearcturus* from near Hereford are

isopod, as also is the little *Archaoniscus Brodiei* found in quantities in the Purbeck Beds of Wilts and Dorset. Several forms are found in Cretaceous and Tertiary rocks, as *Palaega Carteri* (Fig. 48) in the Cenomanian Chalk of Dover, and *Eosphaeroma Smithi* in the Eocene of the Isle of Wight. One tribe of Isopoda, the Epicaridea, live as parasites on other Crustacea, notably on prawns, causing distortion of their carapaces. The distorted carapace seen in some specimens of *Palaeocorystes*, a crab from the Cambridge Greensand, suggests that they harboured these parasites.

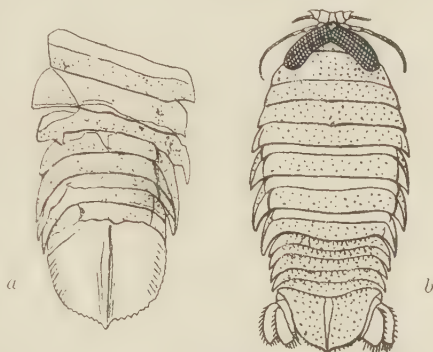


FIG. 48.—Isopods, fossil and recent. *a*, *Palaega Carteri*, Cenomanian Chalk, Dover; *b*, *Aega monophthalma* from the Moray Firth.

The Order **Amphipoda** contains the sand-hoppers and fresh-water shrimps; small animals with a body flattened from side to side, and with gills attached to the thoracic feet. A few have been found in Tertiary rocks, but are not represented in the Museum.

The Order **Stomatopoda** comprises but a single family, the Squillidae, of which all living representatives are marine. Resembling lobsters in general form, they differ in having the carapace so short as to leave the hinder segments of the thorax uncovered, in having none of the thoracic limbs modified as jaws, but the first five pairs bearing pincer-claws which are especially large on the second pair, and in having gills borne only on the limbs of the abdomen. *Squilla*, well-known in modern seas, is found in the London Clay, the Cretaceous of Lebanon, and the Kimmeridgian of Solenhofen (note the larval stages called Protozoëa). *Necrosquilla*, based on an abdominal fragment from the Middle Coal Measures of Derbyshire, is placed in this Order provisionally.

The large Order **Decapoda** (lobsters, prawns, crabs) owes its name (ten feet) to the fact that the hinder five pairs of thoracic limbs are strongly developed as either walking or swimming legs or as pincers (k-o in Fig. 45); gills attached to these limbs are covered by the carapace. Three pairs of

Gallery
VIII.
Table-case
22.

Wall-case
13A.
Table-case
22.

Table-cases
22-20.
Wall-cases
13A, 12c.

Gallery
VIII.

limbs in front of these are called maxillipeds, because they assist the mandibles and the two pairs of maxillae in the work of jaws; and the two pairs in front of all these act as feelers. The fossil Decapoda belong to two Sub-Orders, the **Macrura** (long-tails) and the **Brachyura** (short-tails). These represent two grades of structure, the former being the older; and the most interesting among fossil Decapoda are those that cast light on the evolution of the short-tails from the long-tails, or, as one may put it broadly, the change of lobsters into crabs.

The British series of fossil decapods is arranged under the time divisions: Jurassic, Cretaceous, and Tertiary; and within each of these divisions the Macrura are placed before the Brachyura. True decapods are first found with certainty in Lower Triassic rocks, but these are only represented in the foreign series.

We shall now take those tribes of Decapoda that are found fossil, in an order corresponding approximately to that of their appearance in the rocks. This order agrees with an arrangement according to grades of structure, the most simple and primitive coming first.

Table-case
22.
Wall-case
13A.

In the foreign Trias and in the Lower Lias of England is found a long-tailed genus *Aeger*, in which the first three pairs of thoracic legs bear pincer-claws as in the lobster, but here the third pair is much the largest. For this reason and because of its general form, *Aeger* is held to be an ancestor of the tribe **Stenopidea**. It is also found in the Kimmeridgian lithographic stone of Solenhofen.

Table-case
22.
Wall-case
13A.

A large prawn, common in the Mediterranean and called *Penacus*, differs from true prawns in having the first three pairs of thoracic legs all much of a size and all provided with pincer-claws. The tribe **Penaeidea**, of which this is typical, is also supposed to be represented in the Trias. The early fossils, however, are rather doubtful, and it is in the Solenhofen stone that we first certainly meet with Penaeidea in the genera *Atrimpos*, *Acanthochirus*, *Bylgia*, *Drobna*, *Dusa*, and others. *Penacus* itself is found in the Senonian rocks of Westphalia. A few examples of the tribe occur in Tertiary strata.

The true prawns and shrimps, which with their allies form the tribe **Caridea**, have pincer-claws on the first two pairs of legs, and have the side-plates of the second abdominal segment broadened so as to overlap those of the segments in front and behind. Owing to their comparatively tender

outer covering they are not common as fossils. *Udorella* of the Cretaceous of Lebanon is probably an ancestral form derived from the Penaeidae. The common British prawn and the river-prawns of the tropics belong to a family Palaemonidae. Some fossils of this family found in the Oligocene Osborne Beds of the Isle of Wight are exhibited.

Gallery
VIII.
Wall-case
12c.

Table-case
20.

Among the more conspicuous crustaceans in the Liassic rocks of England is the genus *Eryon*, of which the first representatives occur in the foreign Trias. These are the earliest examples of the still extant tribe **Eryonidea**, in which the first four pairs, and sometimes all five pairs, of legs bear pincer-claws. The existing genera are confined to the deep sea, and, like many other deep-sea animals, are blind. It is, however, plain that the fossil *Eryon* lived in much shallower waters. The genus is found also in the Solenhofen Stone, which was apparently deposited in a lagoon (Fig. 46, 3). Its latest species is of Neocomian age.

Table-case
21.

Wall-case
13A.

Next we notice the many fossils of *Glyphaea* (Fig. 45) representing the extinct family Glyphacidae. These are of much interest as the ancestors of all the recent **Loricata**, a tribe represented in modern seas by the Palinuridae and Scyllaridae. The Palinuridae are familiar through the rock-lobster, the langouste of the French (*Palinurus vulgaris*); the body is more or less cylindrical, and the antennae are long, cylindrical, and jointed. In the Scyllaridae the body is flattened, and the antennae are expanded into broad plates, which are said to be used as shovels in burrowing. All these lobster-like forms may be distinguished from true lobsters by the absence of pincer-claws, though in the female the last pair of legs has them imperfectly developed. Now the Glyphacidae have antennae still of primitive form, with a stalk of many segments none of which are joined to the upper lip-plate as they are in recent Loricata, and with a feeler-portion only moderately developed; the legs have no regular pincer-claws, but there is a tendency towards their formation in the first pair, which is larger than the rest; they all have a small pointed rostrum. Along with *Glyphaea* we find *Scaphicus* and *Preatya* in the Lower Lias of England. These were preceded by *Pemphix*, of which there are specimens from the foreign Trias, and were followed by *Pseudoglyphaea* in Liassic and Oolitic rocks, by the long-limbed *Mecochirus* of Oxfordian and Kimmeridgian age

Table-case
21.

Table-case
21.

Wall-case
13A.

- Gallery (Fig. 46, 4), and by *Meyeria* in the Lower Cretaceous series. The earliest representative of Palinuridæ appears to be VIII. *Palinurina* from the Lower Lias of Lyme Regis. Following Table-cases 21, 20. this in Upper Cretaceous beds and in the English Eocene is *Podocrates* [*Thenops*], scarcely to be distinguished from Wall-case 12c. *Linuparus* now living in Japanese waters. *Cancrinus*, also a Solenhofen genus, possibly led to the Scyllaridæ, which are Table-case 21. represented in the English Gault and London Clay by *Scyllaridia*, and in the Chalk by *Scyllarus*.

- The true lobsters and crayfish are examples of the tribe **Astacidea**. These forms have pincer-claws on the first Table-case 21. three pairs of legs, and the first pair is very large. Already in the Lias we meet with *Eryma*, which is also found with Wall-case 12c. *Pseudoastacus* in the Solenhofen stone; these two, especially the latter, are very like the freshwater crayfish. In the Table-cases 21 and 20. Chalk, *Enoplocytia* is fairly common and strikingly lobster-like. But *Hoploparia*, found in Cretaceous and Tertiary rocks, is even more closely allied to the modern lobster (*Homarus*) and its near relation *Nephrops*, of which the Norway lobster is a familiar example.

- Callianassa* is a characteristic genus of the tribe **Thalassinidea**, burrowing forms, with a soft, loosely built body. In recent species of the genus the end segments of the first leg with its pincer-claw are greatly enlarged and flattened for shovelling; but this is only in one leg of the pair. From Table-case 21. the Kimmeridge Clay of England comes *Callianassa isochela*, in which this flattened claw is not so disproportionately enlarged and is found in both legs of the first pair; the preservation of the abdominal segments in this fossil suggests that they were not so thin-skinned as in later forms. In Cretaceous and Tertiary rocks the characteristic Wall-case 12c. claws are found, but not the abdominal segments as a rule.

We come now to the **Brachyura**. Typical modern crabs differ from the decapods thus far described in the following characters among others: the abdomen is short and so bent up under the body that it is quite or almost invisible from above; the segment in front of the telson bears no tail-appendages; there are at most nine pairs of gills; the maxillipeds of the third pair are broad and flattened, so as to cover the other mouth-parts; the front feelers are set in cavities formed by partitions that connect the front margin of the carapace with the hard parts of the under surface; the whole body is rarely longer than broad. There is, however, a primitive tribe of Brachyura, the **Dromiacea**, in which these characters

are not developed so constantly or to such an extent. Thus, the outline of the body is longer, more of the abdomen can be seen from above, its last segment often bears small tail-appendages, and in the female the first abdominal segment also has traces of a pair of limbs, the gills are more numerous, the cavities for the first feelers are not so clearly defined. In these characters the Dromiacea approach the Macrura, and it has been shown that they more particularly resemble the true lobsters. A peculiarity, not derived from the lobsters, is that in the Dromiacea the last pair or two pairs of thoracic legs are turned on to the back, where, by their hooks or claws, they hold a bit of sponge or some such object, under which the animal is completely hidden. It is to this tribe that most of the early fossil Brachyura probably belong, although this cannot be determined with certainty, because the tender-skinned abdomen is very rarely preserved. A starting-point for the tribe is furnished by *Prosopon*, British specimens of which from the Great Oolite are here exhibited. First found in Bajocian beds, it persisted to Neocomian times. The carapace, which alone is known, is elongate and closely resembles that of *Homalodromia*, now living in the West Indies, and apparently the most primitive of recent Dromiidae. Another precursor of this family was

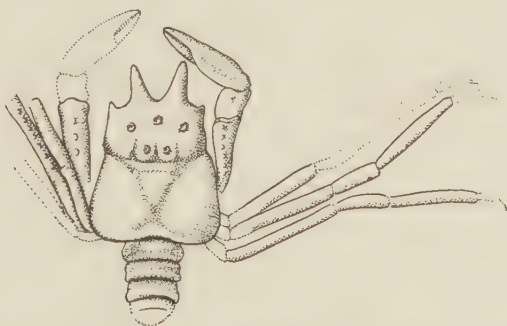
Gallery
VIII.Table-case
21.

FIG. 49.—An ancestor of the Crabs, *Protocarcinus longipes* of the tribe Dromiacea, Great Oolite, Wiltshire. (After Bather.)

Protocarcinus, found in the Forest Marble, fortunately with its limbs. The unique specimen disappeared when its owner died; but a plaster cast is exhibited, and the drawing (Fig. 49) made from this shows the primitive nature of the carapace, abdomen, and limbs. The English Gault has yielded *Homolopsis*, which appears to lead from *Prosopon*

Gallery
VIII.

towards the family Homolidae. *Dromiopsis*, found in the Upper Chalk of Denmark, is an obvious representative of the Dromiidae, and *Dromilites* (Fig. 46, 1), of which there is shown a good series from the London Clay, is scarcely different from the modern *Dromia*.

Nearer to the true crabs is the tribe **Oxystomata** (the Sand-crabs), which owes its technical name to the fact that the mouth-frame is narrowed in front and projects forward between the eyes. In most crabs the mouth-frame is square, and the channels that carry the outward stream of water from the gills open at its two front corners; here, however, they are carried forward to the front of the head, and closed below by plates connected with the first maxillipeds. The reason for these changes is, that the Sand-crabs bury themselves in sand, leaving only the eyes exposed. This tribe appears later than the Dromiaceae, its earliest example being

Table-case
20.

Mithracites vectensis, from the Lower Greensand of Atherfield. In the English Gault and Upper Greensand are found *Palaeocorystes* (Fig. 44, 2), *Eucorystes*, *Neerocarcinus*, *Orithopsis*, and *Trachynotus*. The precise relations of these to modern families are doubtful. The family Raninidae, found first in the

Wall-case
12c.

Cenomanian Chalk, and not rare in Tertiary rocks, is illustrated by foreign specimens from the Eocene of Kressenberg and Scinde and the Miocene of Gironde. Other families, represented by genera still living, also appear in Tertiary times; *Calappa*, for instance, is represented in the British series by fragments of Eocene, Oligocene, and Pliocene age.

Table-case
20.

The tribe **Oxyrhyncha**, characterised by a triangular carapace, with the apex produced in front as a rostrum, is not common in the fossil state. The common genus *Maia*—

Table-case
20.

the spider-crab—is, however, represented by specimens from the Coralline Crag of Suffolk, where it must have lived as nowadays, covering itself with masses of bryozoans and seaweed.

The crabs of the tribe **Catometopa** have a squarish carapace with front strongly bent downwards. Their earliest representative is the Upper Cretaceous *Lithophylax*, a doubtful and rare form not shown here. In Eocene rocks they are less rare, and here is to be seen the original of *Goniocypoda Edwardsi* from Hampshire.

Table-case
20.

The majority of fossil crabs belong to the tribe **Cyclometopa**, in which the carapace is, as a rule, broader than long, with the front curved and not produced into a rostrum. With the exception of the river-crabs, all modern forms of

this tribe live in the sea. Among the oldest genera are *Etyus* from the Gault and Cambridge Greensand, and *Xanthosia* from the Greensand of Warminster and Cambridge. *Xanthopsis* is common in the London Clay, and specimens are also shown from the Tertiary rocks of Bavaria and China. In the British Tertiary series are to be noted remains of a spiny *Rhachiosoma* (Fig. 50), of the swimming crab *Portunus*,

Gallery
VIII.
Table-case
20.

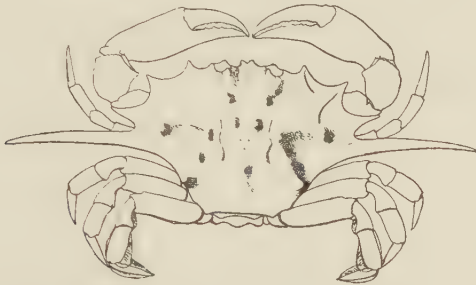


FIG. 50.—A fossil crab, *Rhachiosoma bispinosa*, of the tribe Cyclometopa, Lower Eocene, Portsmouth. (After H. Woodward. Restored from specimen in Table-case 20.)

and of the edible crab *Cancer*. A very large species of the latter comes from Patagonia, and there are some large examples of a *Scylla* from the Philippines. The river-crabs are represented by *Potamon* [*Thelphusa*] from the freshwater Miocene beds of Oeningen.

Wall-case
12c.

CLASS DIPLOPODA (Millipedes).

The millipedes of to-day are inhabitants of the land, with a distinct head and a worm-like body of many similar segments, each enclosed in a horny ring. Many of the segments bear two pairs of legs apiece, and thus represent two primitive segments fused together. In some millipedes the under part of the ring still consists of two plates, one to each pair of legs. In many Palaeozoic millipedes not only does each segment bear two pairs of legs, but, both on the back and on the under side, the ring is composed of two plates. On the side of each segment, near the attachment of the legs, is an opening. These openings, called stigmata, lead to the tracheae or air-tubes by which the animal breathes. The head bears two clusters of eyes and a pair of short feelers or antennae, and is furnished underneath with two pairs of

Gallery
VIII.
Table-case
20.
Wall-case
12c.

jaw-limbs, the mandibles and the maxillae, the latter joining to form a lower lip.

Millipedes of modern character are found in Tertiary rocks, especially in amber, e.g. *Julus* and *Polyxenus*. The Mesozoic rocks furnish a single doubtful form, *Julopsis*, of Cretaceous age, and a few from the Trias. The Palaeozoic forms above referred to occur in the Devonian and Carboniferous rocks. In the British series are exhibited *Euphoberia*



FIG. 51.—A fossil Millipede, *Euphoberia ferox*, Coal Measures, Coalbrookdale, Shropshire. Natural size.

The British series are exhibited *Euphoberia*

(Fig. 51) and *Xylobius* from the Coal Measures.

CLASS CHILOPODA (Centipedes).

Superficially like the millipedes, the centipedes differ in never bearing more than one pair of legs on a body-segment, and in having four pairs of jaw-limbs. The stigmata lie in the membrane between the horny rings of the segments. These also being dwellers on land, are not common as fossils, and up to the present are not represented in the Museum.

CLASS INSECTA.

Table-case
20.
Wall-case
12B.

The insects are the most highly modified of Arthropoda. Like the centipedes they breathe by tracheae and have a long segmented body; but in addition to a distinct head, the hinder part of the body is sharply divided into a thorax of three segments in front and an abdomen of nine or ten segments behind, and it is only the thorax that retains legs, these being always in three pairs. The head bears a pair of compound eyes, a pair of antennae, and three pairs of jaw-limbs. Most insects have on the thorax two pairs of wings.

Owing to certain difficulties attending the study of fossil

insects, notably the slight appeal which their crushed fragments make to entomologists, it has not as yet proved possible to arrange an exhibited series in such a manner as either to indicate the riches of the Museum or to give a clear view of the palaeontological history of the Class. Here then it can only be stated that, although the earlier insects of Palaeozoic age have a primitive character, still they can be connected with some of the Orders into which modern insects are divided. Other of those Orders first appear at a rather later date. The Orders are: 1. **Aptera**, wingless insects, including the spring-tails, first found in the Carboniferous. 2. **Orthoptera**, including cockroaches, possibly from Silurian, certainly from Carboniferous onwards; earwigs, beginning in Lias; grasshoppers and the like, from Lias onwards. 3. **Neuroptera**, including may-flies, dragon-flies, caddis-flies, and white ants; ancestral forms are found as far back as the Devonian if not before; more modern types come in with the Mesozoic Era. 4. **Hemiptera**, including bugs, plant-lice (Aphidae), and scale insects; an hemipterous wing has been found in the Upper Ordovician of Sweden, and more nearly complete fossils from the Carboniferous onwards, while modern families begin in Mesozoic rocks. 5. **Coleoptera** or beetles are not certainly known before the Triassic Epoch. 6. **Diptera** or flies are first found in the Lias, but are neither numerous nor readily identified before Tertiary times. 7. **Lepidoptera**, or butterflies and moths, are as yet known only from Tertiary strata. 8. **Hymenoptera**, including bees, wasps, ants, and gall-flies, are represented by ants in the Lias, but are mostly found in later Tertiary beds.

In the **British** series, the Orthoptera of the **Coal Measures** include forms allied to cockroaches, among which the specimens of *Ectoblattina* (Fig. 52) and *Leptoblattina* are noteworthy. Nodules of the same age contain wings of the Neuroptera *Lithosialis* (Fig. 53 a), *Brodrea*, showing bands of colour (Fig. 53 b), and *Lithomantis* with its expanded prothorax (Fig. 54), formerly considered an ally of the recent praying insect *Mantis*. The insects found in **Liassic** rocks are for the most part small and insignificant, but there is a moderate-sized dragon-fly, *Libellula*, from both Lower and Upper Lias; and from the Lower Lias of Barrow-on-Soar near Leicester comes a Neuropteran allied to the white ants and called *Palucotermes*. Elytra of beetles, sometimes with a metallic lustre, are common in the **Stonesfield Slate**,

Gallery
VIII.

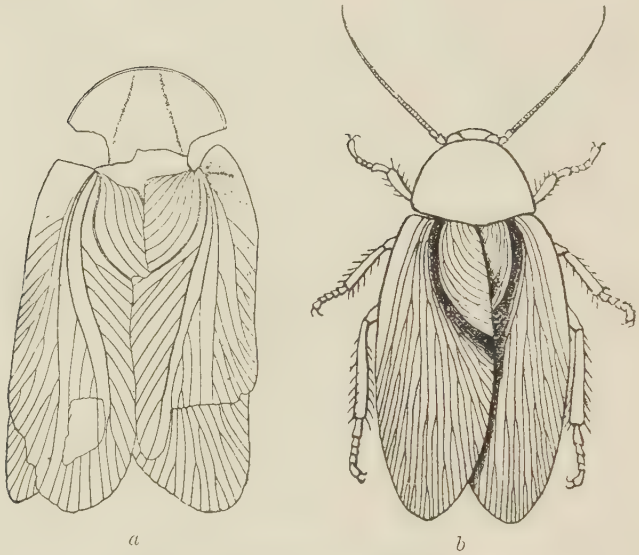


FIG. 52.—Cockroaches of the Coal Measures. *a*, *Etoblattina mazona* from Illinois, enlarged 2 diameters. (After Scudder.) *b*, restoration of *Progonoblattina helvetica* from Switzerland. Natural size. (After Heer.)



FIG. 53.—Wings of Neuropterous insects from the English Coal Measures. *a*, *Lithosialis Brongniarti*; *b*, *Brodiea priscotineta*, with colour-bands. Natural size. (Table-case 20.)

and from this rock comes the almost complete specimen of *Blapsium Egertoni*. *Libellula* may also be noticed from the **Purbeck Beds** and from the Bagshot Beds of **Upper Eocene** age near Bournemouth. These last-mentioned beds, as well as the **Oligocene** Bembridge Beds of Gurnet Bay in the Isle of Wight, have furnished a number of insects belonging to many modern families.

Among the fossil insects from **foreign** localities we notice first some Orthoptera allied to the cockroaches, and some large Neuroptera, from the **Coal Measures** of Commeny, Allier, France; a locality famous for the beautiful examples that it has yielded. The next series of importance is that from the Lithographic Stone of **Solenhofen**; here

Gallery
VIII.

Wall-case
12B.



FIG. 54.—An Insect from the Coal Measures of Ayrshire, *Lithomantis carbonarius*, probably a Neuropteran. $\frac{3}{4}$ natural size. (After H. Woodward.) (Table-case 20.)

we may imagine that numerous insects lived on the islands around a lagoon, into whose placid waters they were constantly being blown. The Orthoptera are represented by the cricket *Pseudogryllucris* [*Gryllucris*], by the locust *Pycnophlebia*, and by *Chresmoda* [*Pygolampis*] *obscura*, a precursor of the Mantidae and Phasmatidae or stick-insects. Among the Neuroptera is the dragon-fly *Cymatophlebia*. Water-bugs allied to *Nepa* and *Belostoma* represent the Hemiptera. Beetles are numerous. The chief example of the Hymenoptera is *Pseudosirex*, one of the tailed wasps that bore into trees. Cretaceous insects are unrepresented, but there are many from **Tertiary** rocks, all of modern type. The Oligocene deposits of Aix in Provence, the Miocene Beds of Florissant in Colorado and of Oeningen on

Gallery
VIII.
Wall-case
12B.

Lake Constance, and the Brown Coal of Rott near Bonn, also Miocene, all furnish their quota. The Indusial Limestone of Lower Miocene age from Offenbach is composed of the cast-off cases of caddis-worms, *Phryganea*. Many insects also come from the Miocene deposits of Radobož in Croatia, and among these a cricket (*Gryllacris Ungerii*) is preserved in a most life-like attitude. Other Miocene insects are seen in amber cast up on the shores of the Baltic, just as they are preserved in the hardened gums of later age from Zanzibar and elsewhere.

Further information may be obtained from "The Fossil Insects of North America," by S. H. Scudder (New York, 1890), and from the handbook by A. Handlirsch, "Die Fossilien Insecten" (Leipzig, 1906-07).

BRACHIOPODA.

Gallery
VIII.
East Side.
Wall-cases
10 & 11.
Table-cases
17-19.
[Also
Gallery XI.
Table-cases
10 & 13-16.]

Following on the Arthropoda, are exhibited the commonest of all fossils, the Brachiopods or Lamp-shells. The important specimens contained in the Davidson and Sowerby Collections have already been noticed. (See pp. 9, 10.)

The Brachiopoda are animals that live in the sea, and have a soft body enclosed in an external shell with two valves (Fig. 55). They thus look something like bivalve

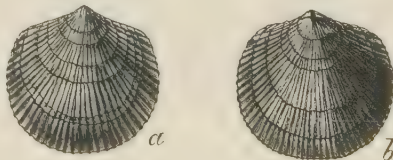


FIG. 55.—Shell of a common Silurian Brachiopod, *Atrypa reticularis*. *a*, ventral or peduncular valve; *b*, dorsal or brachial valve. Shows bilateral symmetry, and slightly greater size of ventral valve.

Mollusca; but both the shell and the soft parts have really a very different structure from those of the Mollusca. So much of the anatomy of the Brachiopoda as is important to the student of fossils, is illustrated by the large coloured diagrams in the wall-cases.

Wall-cases
10 & 11.

The two valves of the shell lie on the back and front of the animal, not on its sides as in bivalve molluscs. Each

valve is symmetrical in itself, its right and left halves resembling one another. On the other hand, one valve is nearly always larger than the other (Figs. 55 *a* and 60 *a*). By the larger valve the adult animal is usually attached to rocks or other objects. In a few forms, such as *Crania* (Diagram 1), the valve is directly cemented to the rock by its own substance. In others, such as *Lingula* (Diagram 2 and Fig. 57), the valve is attached by a long muscular stalk, the "peduncle" or "pedicle," which is capable of waving movement and of contraction. There are also intermediate stages, with shorter peduncles, such as *Hemithyris* (Diagram 8) and *Orbiculoidea* (Fig. 58 *b*). This larger, attached valve is therefore often called the "peduncle valve": by English writers it is called the "ventral valve," although in the natural position of stalked forms it is always the uppermost. Similarly the smaller valve is called the "dorsal valve"; but a better name is "brachial valve," which reminds one that this valve often bears a calcareous skeleton supporting the so-called "arms" (Diagram 9 and Figs. 59, 60).

In microscopic structure also the shell differs from that of the Mollusca (Diagram 3). It is mainly composed of small prisms of calcite (carbonate of lime), which usually lie at right angles to the surface of the shell. In the harder-shelled forms these make up the greater part of the shell, merely being coated on the surface with a layer of slightly different texture and with a thin horny membrane. In the softer-shelled forms, such as *Lingula*, horny substance occurs not merely on the surface, but in layers between the prisms, which in this case are of phosphate of lime. In many genera, such as *Terebratella*, *Crania*, *Cistella*, the shell is perforated by a number of small canals; these contain processes of the mantle, the arrangement of which is shown in Diagram 3*a*. In fossils this structure gives to the exterior of the shell a pitted or "punctate" appearance under a magnifying glass, and thus enables one to distinguish such shells from those which are "impunctate," as the shells of Atrypidæ and most Rhynchonellidæ.

The shell-valves are secreted by the two mantle-folds which line them. These are extensions of the body-walls, and they contain prolongations of the body-cavity, in which is a blood-like fluid and in which the generative products are formed. These vessels often produce impressions on the inside of the shell, and so can be traced in the fossils, e.g. *Camarophoria* (Fig. 56) and a fine specimen of *Orthis*

Gallery
VIII.

(*Schizophoria*) *striatula*. The outer edges of the mantle-folds are set with bristles (setæ). All these structures are shown in Diagrams 5 and 11.

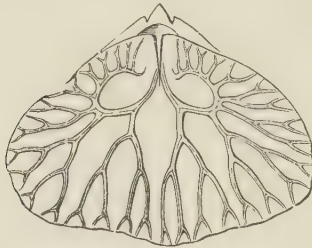


FIG. 56.—The internal cast of a Brachiopod shell from Permian rocks, *Camarophoria Schlotheimi*, showing the impressions of vessels in the mantle-fold.

Muscles pass across the body of the animal from one shell-valve to the other (Diagram 6); they serve to open and to close the valves, and to move them sideways. The attachment of these muscles to the shell forms scars, which in fossil brachiopods are the only evidence we have as to the arrangement of the muscles. The drawing from life of the inner surface of a *Lingula* shell (Diagram 7 and Fig. 57) should

be compared with Diagram 8 showing the muscles.

The viscera lie near the hinder or peduncular end of the shell, with the mouth directed towards its forepart or

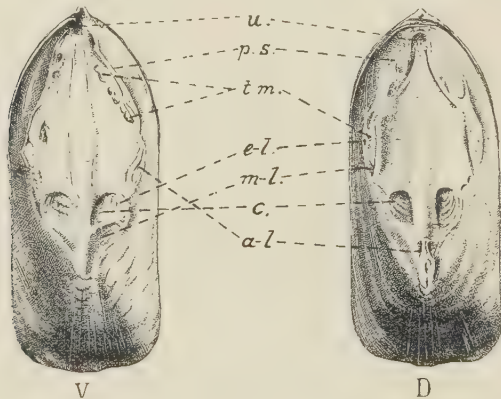


FIG. 57.—The muscle-scars of the Recent *Lingula anatina*. Interior of V, ventral or peduncular valve, and D, dorsal or brachial valve. *u*, umbonal; *p.s.*, parietal; *tm*, transmedian; *e-l*, externo-lateral; *m-l*, medio-lateral; *c*, central; *a-l*, antero-lateral.

opening. The mouth is surrounded by a somewhat horseshoe-shaped disc; this bears tentacles, furnished with minute, rapidly-moving processes (cilia), which drive towards the mouth currents of water containing food-particles; it is

called the "lophophore" (tuft-bearer), and resembles the structure of the same name in the Bryozoa (Diagram 8). The lophophore is generally produced into two so-called "arms," which fill the forepart and sides of the shell-cavity and are often spirally coiled. Since they were formerly supposed to represent the "foot" of the Mollusca, their presence suggested the name Brachiopoda (arm-feet). The mouth leads to a slightly coiled intestine (Diagram 10), which in the simpler genera is provided with an anus, whence the Class comprising them received the name Tretenterata (pierced guts). Fossils indicate that some of the earlier genera of the other Class were also provided with an anus; but in its later genera this structure became degenerate, and no longer exists in the living representatives; for this Class, therefore, the name Clistenterata (closed guts) was proposed. These names are now generally supplanted by Inarticulata and Articulata (see p. 112).

The Brachiopoda are found in seas all over the world, and usually at depths of less than 100 fathoms, but they have been dredged at a depth of 2,900 fathoms. Most kinds attach themselves permanently to a hard bottom by the peduncle, open their shell so far as the hinge permits, and collect minute food-particles in the currents of water that flow down the lophophore; some protrude and even unroll the arms. *Lingula*, as shown in Diagram 2, lives in a tube in the sand, forming a case of agglutinated sand round the lower end of its peduncle; it stretches its shell to the opening of the tube, and the projecting setæ guide the currents of water down to the lophophore; but when disturbed, the peduncle contracts and the shell is withdrawn into the tube, which closes in above. It is not, however, to be inferred that all extinct species of *Lingula* and of similar genera lived in this way.

Though brachiopods usually occur in great numbers wherever found, they are not so numerous now as they were in past ages. In the Carboniferous Epoch especially, the number of species and individuals was very great, and the *Producti* then living reached a larger size than any brachiopod before or since. *Terebratulina grandis*, of the Coralline Crag, is the largest brachiopod found in later rocks. Many examples of masses of brachiopod shells are exhibited, and among them may be mentioned a slab covered with *Lingulella Davisi*, from the Lower Lingula Flags of Upper Cambrian Age, near Tremadoc; Ungulite Grit with *Obolus* and

Gallery
VIII.
Wall-case
11.

Wall-case
10c.

Wall-case
10.
Table-case
17.

Wall-case
10A
&
10B.

Gallery
VIII.
Table-case
18.

Schmidtia from the Upper Cambrian of Russia; a mass of Lower Llandovery sandstone with *Pentamerus oblongus*; groups of *Conchidium Aylesfordi* from the Aymestry Limestone, of its ally *Sieberella galeata*, and of *Atrypa reticularis* from the Wenlock Limestone of Dudley; blocks of Jurassic Age with *Aulacothyris* and various species of *Rhynchonella*; and slabs of Middle Lias, Great Oolite, and Cornbrash, with their characteristic brachiopods.

Table-case
17.
Wall-case
11c.

Wall-cases
10 & 11.

The classification adopted in this Department is that used in the English edition of Von Zittel's 'Palæontology.' This is based on the supposed evolution of the group, and may be followed in the Wall-cases, where the fossils from foreign localities are arranged in zoological order, beginning with the top shelf and following its whole length from left to



FIG. 58.—Types of Brachiopod Orders. *a*, Order Atremata, the Cambrian *Iphidea labradorica*, one of the simplest forms of brachiopod shell. *b*, Order Neotremata, the Ordovician *Orbiculoidea lamellosa*, the peduncular valve, showing the delthyrium, which has become surrounded by the valve and partly filled in from underneath by a shelly deposit. *c*, Order Protremata, the Ordovician *Clitambonites Verneuli*, seen from the side of the brachial valve, above which is the lofty hinge-area of the peduncle valve. The delthyrium is covered by a single pseudo-delthyrium, through which the peduncle passed by the foramen.

right, and continuing on the middle and bottom shelves in the same manner. By attending to this, the genera mentioned in the following account will readily be found.

In those Brachiopoda that appear to be the simplest and oldest, the shells are not as a rule joined by any hinge (Diagram 7). These have therefore been called INARTICULATA or ECARDINES (*e*, without; *cardo*, hinge): they include *Lingula*, *Discina*, *Obolus*, *Crania*, *Trimerella*, and their allies. In more advanced forms, such as *Orthis*, *Leptaena*, *Atrypa*, *Terebratula*, a hinge is developed at the hinder end of the shell (Diagram 4), and these have been called ARTICULATA or TESTICARDINES (*testa*, shell; *cardo*, hinge). As classificatory divisions, however, these are not altogether satisfactory, for the Articulata are necessarily derived from the Inarticulata, and intermediate forms are not rare.

The relations of the peduncle to the valves manifest a gradual evolution. The simplest type is seen in *Iphidea* (from the Cambrian, Fig. 58, *a*) and *Lingula* (Cambrian to present day, Fig. 57), where the peduncle simply passes out between the valves and is not enclosed by either of them; such genera are therefore without a hole (*trema*) through which the peduncle may pass, and constitute the Order **Atremata**. In *Trematis*, *Orbiculoidea* (Fig. 58, *b*), *Siphonotreta*, and their relatives (mostly Ordovician and Silurian), the peduncle is restricted to the ventral valve; it lies in a groove or fissure (delthyrium), which remains open in primitive forms, but closes round the peduncle (forming a *trema*) in later forms: such genera constitute the Order **Neotremata**. Next, the fissure in which the peduncle lies assumes a triangular shape; the peduncle is towards the apex of the triangle, and itself secretes a single shelly plate (pseudo-deltidium), which gradually fills up the triangular fissure till only a small foramen is left at its apex, as in *Clitambonites* (Fig. 58, *c*) and *Rufinusquina* (Diagram 4); later in life the pseudo-deltidium may be reabsorbed, as in the Orthidae: such genera constitute the Order **Protremata**. Some forms have taken another line of evolution: in them the pseudo-deltidium is either absent or soon reabsorbed, so that the delthyrium is open in early life, but at a later period it becomes partly or entirely closed by two "deltidial plates," which are secreted by the edges of the mantle along the sides of the delthyrium, and which may subsequently meet either above or below the peduncle, and may even fuse into one plate, the "deltidium"; these plates are well seen in *Atrypa* and *Stringocephalus*, and occur in *Rhynchonella*, *Spirifer* (Fig. 59), *Terebratula*, and allied forms: such genera constitute the Order **Telotremata**. The arms are often supported by a calcareous skeleton, the shape of which is of great importance in classifying fossil brachiopods. Thus, the Telotremata branched into loop-bearing forms (Diagram 9 and Fig. 60, *Magellania*) and spire-bearing forms (Diagram 9, *Atrypa*, and Fig. 59, *Spirifer*).

The Orders Atremata and Neotremata are equivalent to successive stages of the Inarticulata, and are most abundant in the earlier Palæozoic rocks. From them the Protremata and Telotremata arise as divergent groups, which together are the equivalent of the Articulata. The Protremata were dominant in later Palæozoic time; the Telotremata in Mesozoic.

Gallery
VIII.
Wall-cases
10 & 11.

Gallery
VIII.
Wall-cases
10 & 11.

Many of the collections of fossil brachiopods that have come into the possession of the nation are of great interest, either because they have been obtained from remote parts of

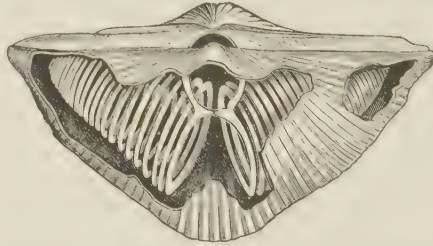


FIG. 59.—An example of the spire-bearing Telotremata, *Spirifer striatus*. Carboniferous Limestone. The shell is seen from the side of the brachial valve, and portions of that valve are broken away, exposing the spires that support the arms of the lophophore. Between the umbones of the peduncular and brachial valves is seen the delthyrium, partly filled in by the deltidial plates that have met and fused above the foramen into a single deltidium. (From the "Cambridge Natural History.")

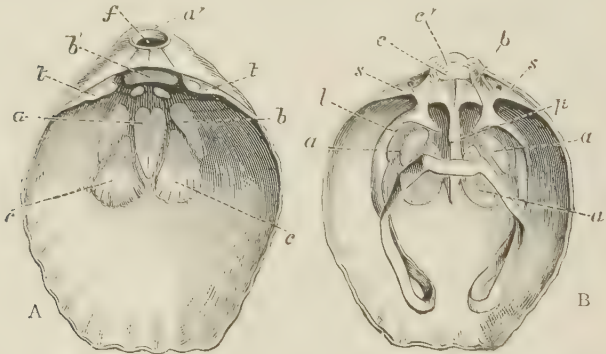


FIG. 60.—An example of the loop-bearing Telotremata, *Magellania flavescens*. Recent seas, Australia. A.—Interior of peduncle valve. *f*, foramen for peduncle, below which are seen the two deltidial plates; *t*, teeth of hinge; *a*, *b*, *c*, muscle-scars; *b'*, scar of peduncular attachment. B.—Interior of brachial valve. *e*, *e'*, cardinal process for attachment of muscles; *b*, hinge-plate, supporting cardinal process and prolonged below into *p*, the median septum; *s*, sockets for the teeth of the peduncle valve; *l*, loop, supporting lophophore; *a*, muscle-scars.

the earth, as the Arctic Regions or the Hindoo Khoosh, or because they have belonged to well-known students of the subject, such as Thomas Davidson and J. F. Walker. Interest of this kind has, however, been taken away from this

exhibited series, and transferred, with all specimens of historical interest, to Gallery XI. An attempt was, therefore, begun to show here specimens interesting from their habit or structure. Such are the examples of *Spirifer*, in which the arm-spines were worked out with a needle and acid by the Rev. Norman Glass, and specimens of *Terebratula* and *Ornithella* from the Cornbrash, showing the arm-loop. The interior of the shell is also well shown in a *Liothyris* from the Norwich Chalk on the other side of the Case. Another Jurassic brachiopod *Acanthothyris spinosa* owes its name to the numerous spines borne by its shell; these were very long and are generally broken off, but there are exhibited both British and foreign examples in which they are most wonderfully preserved and displayed. *Productus* is another genus richly provided with spines, and these owing to their size are often found scattered in the rock as thin tubes; a slab of Carboniferous Limestone covered with them is shown. A pretty impression in flint of the rare *Trigonosemus elegans* is among the Cretaceous fossils. Various Jurassic *Terebratulæ* and terebratuloid shells reflect changes of growth, due to old age or illness, in variations of their ornament. The same outer form has frequently been assumed by brachiopods of different internal structure at widely separated geological periods, a circumstance very perplexing to the field-geologist; but here is exhibited a set of four different species, belonging to at least three genera, all coming from the Inferior Oolite Marl, and so much alike that a casual observer could hardly tell them apart. A similar independent recurrence of form is displayed by *Pygope* and other "diphyoid" genera, in which the fore-part of the shell has grown out into two lobes that ultimately meet and enclose a vacant space. These various modes of growth and of evolution are by no means confined to Brachiopoda. They suggest that living creatures develop in definite directions, which are the consequences of some previous impulse or previous conditions; and that community of a distant inheritance may lead to similar convergent results, especially when the outer stimulus is the same.

Further information on the Brachiopoda may be sought in the memoirs by T. Davidson already referred to, and in "An Introduction to the Study of the Brachiopoda," by J. Hall and J. M. Clarke (Albany, 1904-5).

Gallery
VIII.
Table-case
17.
Table-case
18.
Table-case
17.

Wall-case
11B.
Table-case
17.

Table-case
18.

Wall-case
11B.

BRYOZOA OR POLYZOA.

Gallery
VIII.
Centre-
Cases
A4-A6.
Wall-case
12.

The fossil remains of the Bryozoa (moss-animals), or Polyzoa, as they are often called, a group of which the modern Sea-mats are familiar examples, are exhibited in three cases in the middle of the gallery, adjoining the Brachiopoda, with which they are by some supposed to be allied. These specimens are all British, and form an adequate representation of these widely spread fossils. In Wall-case 12 are placed a few foreign specimens of particular interest, as well as certain colonies too large to find room in the British series proper.

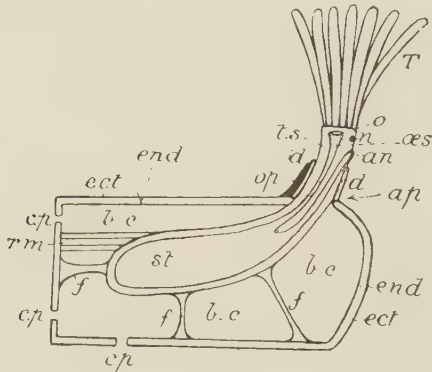


FIG. 61.—Diagram of structure of a typical Bryozoan zooid, as seen in a vertical cut down the middle. *an*, anus; *ap*, aperture; *b.c.*, body-cavity; *cp.*, communication pore; *d.*, diaphragm; *ect.*, ectocyst; *end.*, endocyst; *f.*, funiculi; *n.*, nerve-ganglion; *o.*, orifice; *æs.*, oesophagus; *op.*, operculum; *r.m.*, retractor muscle; *st.*, stomach; *T.*, tentacles; *t.s.*, tentacle sheath.

Though often mistaken by wanderers on the sea-shore for sea-weeds, the Bryozoa are really animals. They live in either fresh or salt water, mostly in the latter, and with one exception (*Loxosoma*), always form colonies, which are generally fixed. A colony consists of a large number of individuals (or zooids), each of which is completely separated from the rest and enclosed in a double-walled sac. The digestive tube is U-shaped, the mouth and anus being placed close together. A band of tentacles occurs round the mouth in most forms (Ectoprocta), but in one group (Entoprocta) this surrounds both the mouth and the anus. These colonies

may spread in delicate gauze-like sheets over weeds, shells, and stones, rise in hard shrub-like tufts, forming hemispherical masses, or stretch out flexible horny branches. In the fossils the soft body of the animal is of course destroyed, and there remain only the hardened walls of the little chamber in which each zooid lived. Fortunately the shapes of these chambers afford characters by which the species can be classified. They must, however, be studied under the microscope. In the arrangement of the collection, therefore, specimens are exhibited to show the general form and habit of the colony, and drawings are placed beside them to show the minute structure of the chambers. The specimens are in most cases near enough to the front of the case to admit of the use of a magnifying glass, and thus the main features of the chambers can be recognised.

Setting aside the aberrant *Loxosoma* and its allies, modern Bryozoa are divided into two Sub-Classes: (1) **PHYLACTOLAEMATA**, in which the mouth of the zooid has a lip, and the crown of tentacles or lophophore is horse-shoe-shaped; (2) **GYMNOLAEMATA**, in which there is no lip to the mouth, and the tentacles form a complete circle. Since the chambers of the Phylactolaemata are either soft or horny, they are not preserved as fossils, so that we are concerned only with the Gymnolaemata. Omitting the doubtful Ctenostomata, of which no fossils are certainly known, these last are divided, according to the structure of the chamber-opening, into four Orders: (1) **Trepostomata** (turned mouths); (2) **Cryptostomata** (hidden mouths); (3) **Cyclostomata** (round mouths); (4) **Cheilostomata** (lip mouths).

The Trepostomata and Cryptostomata are all extinct, but seem to have arisen from early forms of Cyclostomata. The **Trepostomata**, which were dominant in early Palaeozoic times, generally form massive colonies, composed of the chambers drawn out into long tubes and set side by side; the tubes turn upwards towards the openings at their ends; as the colony grew each animal moved up in its tube, the lower part of which was cut off by a platform (diaphragm) like the tabula in Tabulate Corals. Examples are *Monticulipora*, *Stenopora*, and *Callopora* (Fig. 62). In the **Cryptostomata**, which became dominant in later Palaeozoic times, the opening of the chamber is hidden at the bottom of a tubular shaft (vestibule); the chambers grow up into continuous tubes, as in the Trepostomes. Examples are *Ptilodictya*, *Rhabdomeson*,

Gallery
VIII.

and *Fenestella* (Fig. 63). The **Cyclostomata** were dominant during the Mesozoic Epoch; their chambers have simple round openings at their ends, with no covering. Examples:

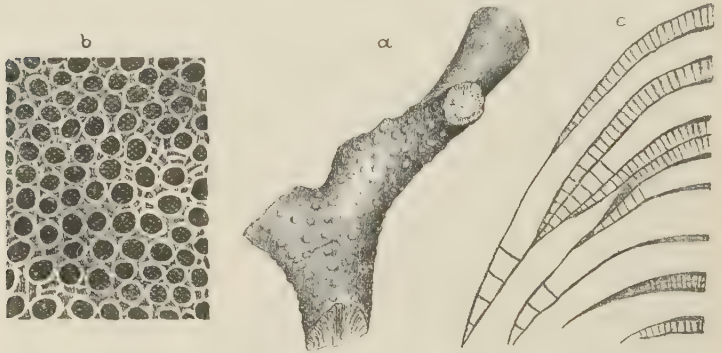


FIG. 62.—A Trepostomatous Bryozoan, *Callopora subnodosa*, Ordovician (Cincinnati group), N. America. *a*, fragment of a colony, natural size. *b*, part of the surface, magnified 12 diameters. *c*, part of a vertical section, showing tubes of differing size crossed by diaphragms, magnified 18 diameters. (After E. O. Ulrich.)

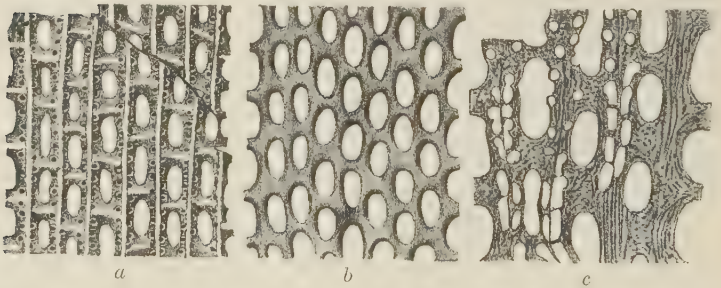


FIG. 63.—A Cryptostomatous Bryozoan, *Fenestella vera*, Devonian (Hamilton group), N. America. *a*, fragment of a colony, obverse, showing the fenestrae, to which the genus owes its name, as white spaces, and the chamber-openings as small dark holes. *b*, reverse of same, showing fenestrae only. *c*, section of same, passing from near obverse surface on left to near reverse surface on right. *a* and *b* magnified 9 diameters; *c*, 18 diameters. (After E. O. Ulrich.)

Stomatopora, *Berenicea* (Fig. 64). In the **Cheilostomata**, which reached their present dominant position in Cainozoic time, the opening is removed from the end of the chamber, is constricted, and provided with a movable lid (operculum).

Examples: *Flustra* (Fig. 61), *Membranipora* (Fig. 65 a), *Onychocella* (Fig. 65 b).

In many Bryozoa certain individuals are modified for special duties. Thus in the Cheilostomes the growth of the operculum has produced snapping beaks, called **avicularia**, and long movable bristles, called **vibracula**; the positions occupied by these appendages can be detected in the fossils (Fig. 65). Sometimes individuals are set apart and modified for reproduction, sometimes special pouches for the reception

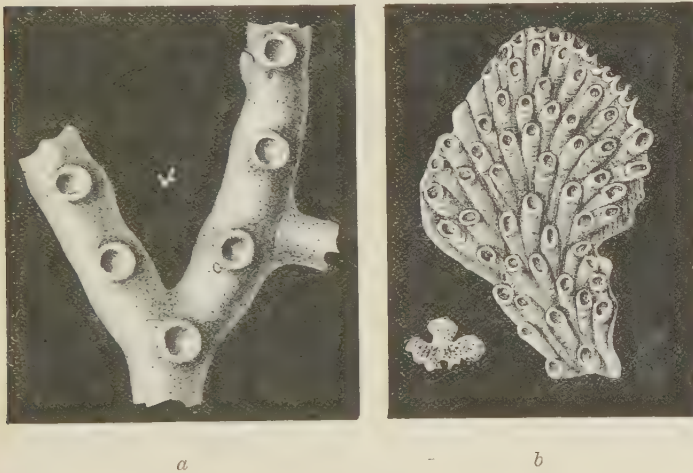


FIG. 64.—Cyclotomatous Bryozoa from the Bathonian (Bradford Clay) of England. *a*, *Stomatopora dichotoma*, part of an encrusting colony, natural size, and magnified 25 diameters. *b*, *Berenicea compressa*, an encrusting colony, natural size, and part of it magnified 12 diameters. (After J. W. Gregory.)

of the developing eggs are attached to the chambers (Fig. 65 a). These modifications suggest explanations for the smaller chambers and tubes interspersed among the normal ones in the fossils of extinct Orders.

We may now briefly review the exhibited specimens. First are shown examples of the mode of occurrence of Bryozoan fossils, the rocks formed by them, and the habit of life of extinct species. Case A4,
West Side.

The **British** series begins with some from the **Ordovician** rocks of Wales. These are so poorly preserved that they can only be determined by the help of better specimens from

Gallery
VIII.

American rocks of the same age. Most of them are Trepostomes or Cryptostomes.

Case A5,
West Side.

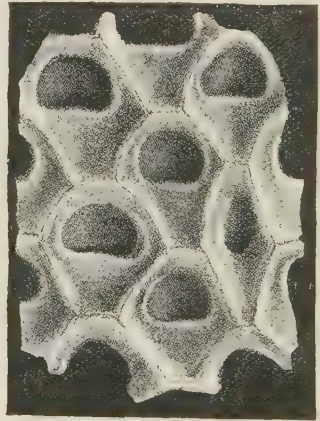
The **Silurian** Bryozoa are in a better state, and the specimens from the Wenlock Limestone include some interesting and elegant Cryptostomes, such as *Ptilodictya sublanccolata*, *Penniretepora Lonsdalei*, and several species of *Fenestella* and *Polypora*.

Case A5,
West Side.

The **Devonian** fauna is small, and its representatives not well preserved; a specimen of *Fenestella prisca*, figured by Phillips, and a *Polypora populata* are worth notice.



a



b

FIG. 65.—Cheilostomatous Bryozoa, from cretaceous rocks. Enlarged 24 diameters. *a*, *Membranipora* sp., from the Senonian (zone of *Micraster cor-anguinum*) of Oxfordshire, portion of a colony; in front of the large chamber-openings are in some cases small depressions left by avicularia, in others round openings leading into egg-pouches. *b*, *Onychocella pyriformis*, from the Maestricht Limestone, portion of a colony; on the right is a chamber much narrower than the others, indicating that the individual was turned into an avicularium.

Case A5,
West Side.

The **Carboniferous** Bryozoa, on the other hand, are numerous and show their structure well. The commonest genus is *Fenestella*, and the size to which its colonies may attain is exemplified by two specimens mounted on blocks. The fan-shaped species of this genus and of *Ptilopora*, the feather-shaped *Penniretepora*, and the cylindrical *Rhombopora*, are the most interesting forms in the British Case. *Hennitrypa* should not be overlooked, as it consists of a colony formed of two layers, of which the upper was once regarded as a coral growing as a parasite on a *Fenestella*. All the genera just mentioned are Cryptostomes.

Wall-case
12A.

Case A5.

The **Permian** species are few; but three larger masses of *Fenestella* and *Synocladia*, another Cryptostome, are mounted on blocks.

Gallery
VIII.

The next fauna represented in England is that of the **Jurassic** system. This shows a great advance on that of the Palaeozoic; old types such as *Fenestella*, *Penniretopora*, *Acanthocladia* disappear, and species belonging to existing genera form the larger part of the fauna. Among these the Cyclostomes, *Stomatopora*, *Berenicea*, and *Diastopora* are important, and are illustrated by an extensive series of specimens, but *Theonoo* and *Apsendesia* are typically Jurassic. These are associated with forms such as *Ceriopora*, which are survivals of the Trepostomata.

Case A6,
West Side

The ensuing **Cretaceous** fauna in many ways resembles the Jurassic. Trepostomata survive, and the Cyclostomata are still in the ascendant. Examination, however, of the specimens exhibited shows that the Cheilostomata are now fairly abundant, as we may see by the numerous species of *Membranipora* and *Onychoella* (Fig. 65) and the presence of more specialised genera such as *Cribrilina*.

Case A6,
West and
East Sides.

Passing to the **Eocene** we find that the fauna in England became smaller, though that of the Mediterranean Basin at the same period was very large. The forms, moreover, were scarce and dwarfed, as they lived in a sea exposed to the north and cut off from the warm waters of the Mediterranean by a land barrier across Central France and Germany. Hence in our series genera such as *Idmonca* are represented only by small delicate colonies (see also *Idmonca coronopus*, from the Paris Basin), which are in striking contrast to the massive growths exhibited from Italy. In addition to these general differences, the fauna includes a high percentage of peculiar species, among which *Orbitulipora petiolus*, consisting of a disc supported on a short stem (see specimen B. 4349), *Adconellopsis Wetherelli*, and *Notamia Wetherelli*, are the most remarkable. The species of the still existing genera *Schizoporella*, *Smittia*, and *Entalophora*, on the other hand, are quite modern in form. Except for the Cyclostomes *Idmonca* and *Entalophora*, all the genera mentioned in this paragraph are Cheilostomes.

Case A6,
East Side.

The **Pliocene** in England is much richer than the Eocene, and comparison need only be made between the small fragile specimens from the latter and such massive colonies as those from the Crags, to realise that the Bryozoa were then living under more favourable conditions; the

Case A5,
East Side.

Wall-case
12A.

Gallery
VIII.
Case A5.

Arctic Ocean was probably cut off by a land barrier to the north, while there was free communication with the seas to the south. The Museum possesses the specimens used by Busk in writing his monograph on the "Crag Polyzoa," and many of them are exhibited. The most interesting forms found in the Crag are some massive Cyclostomes, including the three species known as *Alveolaria semiovata*, *Fascicularia aurantium*, and *F. tubipora*. Among the Cheilostomes, the most remarkable forms are two species of *Cellaria* [*Sabicornaria*] and one of *Melicerita*. The numerous species of *Schizoporella*, *Mucronella*, and *Membranipora* are closely allied to or identical with living forms.

Case A5.

A small collection of **Pleistocene** species from the Clyde and from Selsea Bill is shown; but all these species still live on the English coast.

Wall-case
12A.

The Bryozoa from **foreign** localities are not yet completely arranged, and only a few representative species are exhibited. The lowest slope of the wall-case is devoted to the **Palæozoic** faunas, chief of which are those from the Ordovician and Silurian rocks of North America. The Carboniferous fauna of the same continent furnishes some remarkable forms, notably *Archimedes Wortheni*, which is like a *Fenestella* twisted into a screw, and *Evactinopora quinqueradiata*, another Cryptostome with a star-shaped colony.

A collection from the **Bathonian** deposits of Northern France on the middle slope contains several interesting forms, notably *Onychocella jlabelliformis*, which is the oldest true Cheilostome known.

Among the **Tertiary** Bryozoa on the top slope, the large specimens from the Miocene deposits of the Mediterranean are most worthy of notice.

The Trustees have published a Catalogue of the Jurassic Bryozoa (1896), and the first two volumes of a Catalogue of the Cretaceous Bryozoa (1899, 1909), all by Dr. J. W. Gregory.

MOLLUSCA.

Gallery
VIII.
West side
and
Gallery
VII.

These animals derive their name from their soft bodies (*mollis*, soft), which never have any internal skeleton, and rarely any hard appendages capable of preservation as fossils. The glandular skin, however, usually secretes, on a portion of the outer surface called the mantle, a hard shell, sometimes horny in appearance, but usually thickened by a deposit of

carbonate of lime. The fossil remains of the Mollusca consist therefore chiefly of shells, and these in substance and appearance may not differ from shells that one picks up in the fields or on the sea-shore. Such are many of the Post-Pliocene non-marine shells, and *Neritina concava* from the Oligocene of Headon. Usually, however, the horny layers of the shell have entirely disappeared, and are replaced by a secondary deposit of lime that has soaked in from the surrounding rock and hardened or petrified the shell. Sometimes the original lime itself has been replaced by another mineral, such as flint or iron pyrites, and sometimes the whole shell has disappeared, leaving only a cavity in the rock, with an imprint (or external cast) of the shell on its outer walls, and sometimes containing a mass of rock that filled the interior of the shell, and is called an internal cast. This last method of preservation is clearly shown in a large block from the Roach bed in the quarries of Portland, Dorset. Shells preserved in flint are common among fossils from the Chalk, and pyritised shells are generally found in clays of all ages. A few Mollusca possess other hard parts capable of fossilisation; thus several of the cuttle-fish and their allies have horny beaks, which form the fossils called *Rhyncholithes* (beak-stones, Fig. 78), some have horny hooks on their arms, and some, buried in clay, have even left traces of skin, muscles, and eyes (Fig. 86). We can also infer the former presence of certain boring molluscs, such as *Pholas*, by the burrows they have made in the rocks of the old sea-floor.

Mollusca are in some of their forms, such as oysters and snails, so familiar that we need here only recall the fact that they are among the more highly organised invertebrates, having in the simpler types a distinct head, a mouth and complete digestive system, and a thickening on the under side of the body forming a muscular organ called the foot. All molluscs have a nervous system, blood-vessels, a heart, gills of varying origin, and excretory and reproductive organs. Further information on these matters may be sought in the Zoological Department.

The shells of molluscs are built on various plans; the oyster, for instance, has a shell of two valves; the whelk or the snail-shell is all in one piece, and is besides coiled and open only at one end; the nautilus shell is also coiled, but when cut through it is seen to be divided up by partitions into a number of chambers; the tooth-shell, *Dentalium*, is a tube shaped like a tusk, but open at both ends; *Chiton*,

Gallery
VIII.

Upright
Case A1.

Table-case
3.

Centre of
Gallery
VIII.

Gallery
VII.
Table-case
1.

Gallery
VIII.
Table-case
9.

Gallery
VIII.

which may be found creeping on the rocks at low tide, has a jointed shell, and looks like a wood-lice. Examination of the animals that live in these five types of shell shows that they are built on as many plans of structure, and to one or other of these plans all molluscs, except the Palaeozoic Conularida (p. 141), can easily be referred. Therefore the Mollusca are divided into the following five Classes:—

I. **AMPHINEURA**, of which *Chiton* is an example, owe their name to the two nerve-cords that run down each side of the body, which is elongated and symmetrical. The mantle always secretes little plates or spicules of shell-substance. They are divided into two Orders: (a) **Aplacophora**, which have no shell other than the spicules, and therefore are not

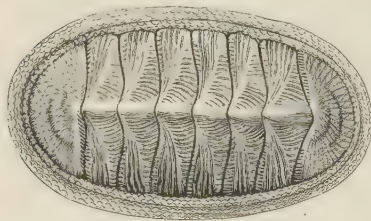


Fig. 66.—Shell of the living *Chiton squamosus*; the front end is to the left.

found fossil; (b) **Polyplacophora**, which have a shell of eight larger pieces, surrounded by a flexible girdle formed of the mantle-edge, in which are usually smaller plates or spicules (Fig. 66). Appearing first in Ordovician rocks, they have persisted till the present day, with increasing elaboration of the shell, but with no

changes of sufficient importance to mention here.

II. **GASTROPODA**, of which the snail *Helix* is an example, derive their name, meaning Belly-foot, from the position of the large foot beneath the stomach and viscera, which are contained in a hump on the animal's back; the surface and folded edges of this hump constitute the mantle that forms the shell. Thus the shell is a cone, sometimes short, as in the limpet (*Patella*), but generally long, and coiled either in one plane as in the ram's-horn snail (*Planorbis*), or spirally as in *Helix* (Fig. 68, 7). In the common snail it may easily be seen that the edges of the mantle form a cavity (the pallial chamber) on the right side of the animal; and into this open the anus and genital duct, which have been brought towards the mouth end of the body by the curving upwards of the viscera into the hump. In many gastropods this twisting of the end of the gut forwards and to the right side has affected other organs and notably the nerve-cords. This affords a basis for dividing the Gastropoda into two Sub-Classes:—

(a) **STREPTONEURA** (twisted nerves), in which the loop formed by the visceral nerves is twisted. Since the gill-cavity is in front of the heart, they are also known as the Order **Prosobranchia**. Example: the whelk, *Buccinum*. To this Order are now referred certain small gastropods (e.g. *Carinaria*), with very thin shells and a muscular expansion forming a vertical fin by which they swim near the surface of the sea. They are sometimes distinguished as **Heteropoda**; some are found in Tertiary rocks.

(b) **EUTHYNEURA** (straight nerves), in which the nerve-loop has untwisted. These are again divided into the Orders: **Opisthobranchia** (hind-gills), marine forms, e.g. *Bulla*; and **Pulmonata** (with a lung, i.e. air-breathers), terrestrial or fresh-water forms, e.g. *Helix*. With the Opisthobranchs are now placed some small thin-shelled gastropods in which the foot is changed into two wing-like fins, one on each side (Fig. 67). They were formerly considered as a separate Class, **Pteropoda** (wing-foot), to which the Conularida were also referred.

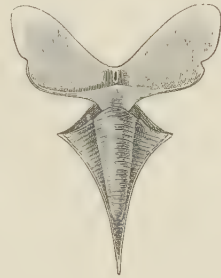


FIG. 67.—A "Pteropod" living in the Atlantic, *Cleodora pyramidata*. Natural size.

Gastropods already existed in early Cambrian times, but all through the Palaeozoic Era they remained of simple type, being mostly marine Streptoneura. The number of genera and species increased greatly during Mesozoic time, but it was not till the later Jurassic and earlier Cretaceous rocks that non-marine forms were preserved in any abundance. In the older Tertiaries most of the genera are the same as those now living, though the species are different. During the Miocene Epoch a few modern species made their appearance, and of the Pliocene species about 85 per cent. have persisted to the present day. On this gradually increasing proportion of recent species of Mollusca Lyell based his division of Tertiary time into Eocene, Miocene, and Pliocene.

III. **SCAPHOPODA** (digger-foot), of which *Dentalium* is an example, have a foot adapted for burrowing in mud or sand. The shell is tubular, since the folds of the mantle have grown together on the under side of the animal; its broader front end, from which the foot can stretch out, is sunk in the sand, while the narrower hind end projects above it and discharges the waste products. Scaphopods

Gallery
VIII.

have endured with little change from the Silurian Epoch to the present day.

IV. **LAMELLIBRANCHIA**, of which the oyster and cockle are examples, usually have complicated gills (branchiae) formed of many lamellae or plates; the foot is rarely used for crawling, but is generally wedge-shaped, whence they are also called **PELECYPODA** (hatchet-foot). These features are naturally associated with a sedentary habit of life and with the suppression of the head-region. The shell is not deposited by a visceral hump, but by two flaps of the mantle, placed on the right and left sides; hence it consists of two valves, which are joined along one edge by a ligament and generally a hinge, and can be closed by powerful muscles (adductors). The lamellibranchs are confined to the water, and most are marine. Some, like the oyster, are fixed; most burrow in mud or sand, and a few bore into wood or rock. This Class, as a whole, presents a somewhat uniform structure, and it can hardly be said that any of the numerous attempts to divide it into Orders has met with general acceptance. Therefore we shall only indicate some of the chief variations that can be seen in the shell. These are: (1) the adductor muscle-scars, whether two equal, two unequal, or only one; (2) the outline of the mantle-attachment (Fig. 68, 2), whether simple or indented by a sinus due to certain muscles that work tubular extensions of the mantle called siphons (but the absence of a sinus does not imply the absence of siphons); (3) perfect or deficient symmetry of the shell-valves; (4) shell-structure, whether porcellanous or nacreous; (5) the arrangement of the ligament; (6) the hinge (Fig. 69, *g*), whether plain or toothed, and the varying numbers and development of the hinge-teeth.

A few ill-preserved shells, apparently of simple Lamellibranchs, have been found in the Cambrian rocks of Wales, Thuringia, and North America. In Ordovician rocks they are still rare, but in Silurian times a score of families existed, mostly with thin shells of simple type. The Devonian saw the beginning of brackish and fresh-water lamellibranchs; these increased in Carboniferous times, when also appeared *Allorisma*, the first form known to have a retractile siphon. With the Trias many of the older genera disappeared and new families came in, followed by others in the Jurassic period, when also *Trigonia* arose and soon flourished in numbers (Plate V.). Among Cretaceous lamelli-

branches the Rudistae are remarkable and characteristic. The early Tertiary fossils are evidence of a gradual change to present conditions, both in the character of the molluscan fauna and its eventual distribution in the same provinces as are at present recognised.

Gallery
VIII.

V. **CEPHALOPODA** (Head-foot), of which the Nautilus and cuttle-fish are examples. These are exhibited in Gallery VII. We shall therefore leave them for the present, and confine our attention to Gallery VIII., which contains fossil shells of only the first four Classes, viz. :—

**AMPHINEURA, GASTROPODA, SCAPHOPODA,
LAMELLIBRANCHIA.**

Gallery
VIII.
Wall-cases
1-9.
Table-cases
1-16.
Centre-
cases A1-
A3 and A7.

It will be most convenient to start with the **British** specimens. Beginning at the main entrance to the Gallery, and following the numerical order of the Table-cases, these are arranged under the larger stratigraphical divisions, with the newest first.

Table-cases
1 & 2.

Post-Pliocene. The **marine** forms are separated from the non-marine, and are arranged under geographical districts in the following order: S. England, Selsea, &c.; S.E. England, including Norfolk; N.E. England, chiefly Yorkshire; W. England, Gloppe, near Oswestry; Wales, Moel Tryfaen; Ireland, the Wexford gravels and Belfast; Scotland, Clyde series; E. Scotland, chiefly Dyer's Burn and Golspie; W. Scotland, including the Lewis. Some of these date from the Glacial period, others are later, as indicated on the label in each instance. They come from raised beaches, glacial drift, and other deposits, and are often found far above present sea-level, as much as 1350 feet at Moel Tryfaen, 1120 feet at Gloppe, and 1200 feet at Calbeck Castle, near Dublin. Some writers have supposed that they were carried to these heights by moving ice. Most of the shells belong to species still existing, and they are as a rule characteristic of northern seas, but southern forms are sometimes associated with them. In the following list of the more important species, the letters N, S, and E respectively denote the Northern, Southern, and Extinct forms:—Gastropoda: *Bittium reticulatum* (S), *Borcotrophon* [*Trophon*] *clathratum* (N), *Littorina littorea* (N), *Neptunea antiqua* (N), *Tricolia* [*Phasianella*] *pulla* (S), *Tritonofusus Leckenbyi* (E), *Turritella communis* (N). Lamellibranchia: *Arca* [*Nucula*] *Cobboldiae* (E), *Arca lactea* (S), *Callista* [*Venus*] *chione* (S), *Cerastoderma* [*Cardium*]

Gallery
VIII.

Central
Case A1.

edule (N), *Chlamys* [*Pecten*] *opercularis* (S), *Cyprina islandica* (N), *Macoma* [*Tellina*] *balthica* (N), *Mya truncatu* (N), *Scrobicularia plana* (S), *Tridonta* [*Astarte*] *arctica* (N), *Ventricicola* [*Venus*] *casina* (S).

The **non-marine** series comprises shells of land and fresh-water mollusca, found chiefly in river drifts and alluvium. These also are arranged under localities, of which the following are the more important: London and Essex (Fulham, Blackfriars, Admiralty Buildings, Lea Valley,

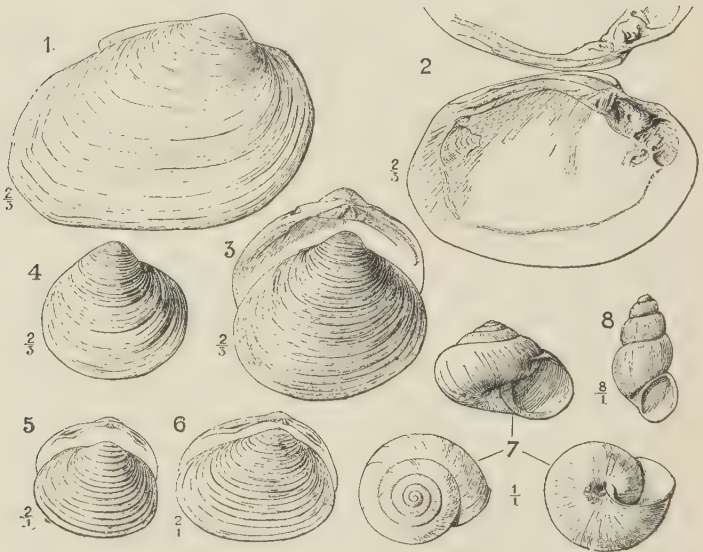


FIG. 68.—Shells of Non-marine Mollusca from the River-Drift of the London District. 1, 2, *Unio littoralis*; 3, 4, *Corbicula fluminalis*; 5, *Pisidium astartoides*; 6, *P. amnicum*; 7, *Helix fruticum*; 8, *Paludetrina* [*Hydrobia*] *marginata*. (Lent by Mr. B. B. Woodward; from his paper in Proc. Geol. Assoc., London, XI., p. 335, 1890.)

Copford, Walthamstow, Witham, Ilford, and Grays); Kent (Crayford and Crossness); Cambridgeshire (Barnwell and Barrington). Most of the species still live in England, but a few are altogether extinct. Thus of those depicted in Fig. 68 only *Pisidium amnicum* remains; other extant species are *Helix nemoralis*, *Jamiania* [*Pupa*] *muscorum*, *Pomatius* [*Cyclostoma*] *elegans*, *Bithynia tentaculata*, *Ancylus fluviatilis*, and *Neritina fluviatilis*, among gastropods, with *Unio tumidus* and *Anodonta cygnaca* among lamellibranchs.

Pliocene. The shells are primarily arranged under the formations from which they come: the Norwich Crag and the Red Crag, both of Astian age; the Coralline Crag, of Plaisancian age; the Lenham beds of Kent and the St. Erth beds of Cornwall, both probably Plaisancian. No rocks of Sicilian age occur in Britain. The Crags are well known for their abundant molluscan fauna, of which further examples, mostly collected by the late Robert Bell, are exhibited in Cases A 2 (Lamellibranchia) and A 3 (Amphineura, Gastropoda, Scaphopoda). The fauna is essentially marine, but a few non-marine shells invite speculation as to the cause of their occurrence. From the Coralline Crag of Gomer, Suffolk, come some fine examples of the gastropod *Voluta Lamberti*, one of them $9\frac{1}{2}$ inches (24 centimetres) long. The Red Crag furnishes *Neptunca antiqua* wound in a reverse direction to the usual one, *Cyprina rustica*, and *Pholas cylindrica*. In the Norwich Crag again appears *Acila Cobboldiae*, and *Bittium reticulatum* is again found in the St. Erth beds.

Oligocene. Shells of this Epoch come from the Hamstead or Hempstead Beds of Rupelian age, the Bembridge Limestone (Tongrian), and the Osborne and Headon Beds (Priabonian). These formations were deposited in an estuary where now are the Isle of Wight and the south of Hampshire. One may notice particularly *Amphidromus* [*Bulimus*] *ellipticus* wound in a reversed or left-handed coil, with many species of the gastropod genera *Viviparus*, *Melania*, *Limnaea*, and *Planorbis cuomphalus*, and the lamellibranchs, *Ostrea*, *Corbicula*, and *Volsella* [*Modiola*]. The eggs of some large gastropod, *Bulimus* or an ally, will be seen preserved in Bembridge Limestone. A slab of Headon Limestone almost entirely composed of the shells of a fresh-water snail, *Limnaea longiscata*, is fixed on the wall.

Eocene. Here are the Bartonian shells of Barton, the Lutetian of Bracklesham, and the Landenian shells from the London Clay, Oldhaven Beds, Woolwich and Reading Beds, and the Thanet Sands. Except for the Oldhaven and Woolwich Beds, which contain both estuarine and marine fossils, all these formations are purely marine. Many of the specimens exhibited have been figured by G. A. Mantell, James Sowerby, F. E. Edwards, and others. A large specimen of *Cardita planicosta* is marked so as to explain the terms applied to the various parts of a lamellibranch shell. Here also is the curious burrowing lamellibranch

Gallery
VIII.
Table-case
2.
Table-cases
2 & 3.

Centre-
cases A2
A3.

Table-case
3.

Between
Wall-cases
2 & 3.

Table-case
4.

Table-case
5.

Table-case
4.

Gallery
VIII.

Stirpulina [*Claragella*] *coronata*, in which a shelly tube is formed round the long siphons while the shell-valves remain quite small and attached to the side of the tube. In addition to the gastropods here figured (Fig. 69), one may note the beautiful *Voluta luctatrix*, the large *Hippochrenes* [*Rostellaria*] *ampla*, and *Xenophora agglutinans*,

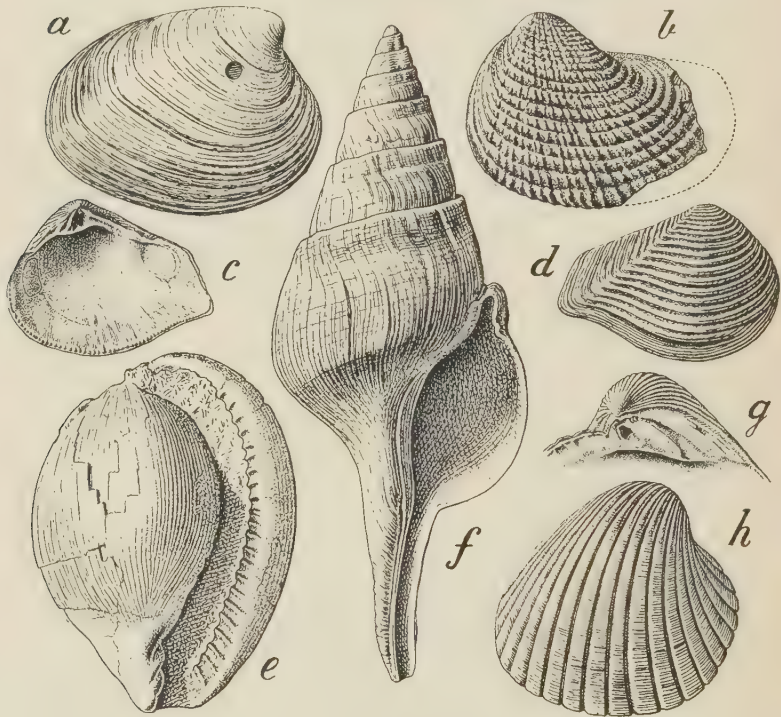


FIG. 69.—Shells of Eocene marine Gastropods and Lamellibranchs. *a*, *Cyprina Morrisi*, Thanet Sands of Herne Bay, Kent; the specimen figured by J. de C. Sowerby; the hole is due to a boring animal. *b*, *Pholadomya virgulosa*, London Clay of Bognor, Sussex; a small specimen. *c*, inside, and *d*, outside of left valve of *Crassatellites sulcatus*, Barton Beds of Hampshire. *e*, *Cypraea Bowerbanki*, Lutetian of Bracklesham, Sussex. *f*, *Clavalthes longævus*, Barton Beds of Hampshire. *g*, the hinge, and *h*, the outside of right valve of *Cardita planicosta*, a small specimen, Lutetian of Bracklesham. *b*, *c*, *d*, *g*, *h*, are natural size; *a*, *e*, $\frac{2}{3}$ natural size; *f*, $\frac{1}{2}$ natural size. (Table-cases 4 & 5.)

one of the carrier-shells that become covered with bits of stone, shell, and other foreign substances. Among London

Clay fossils are the long tubes formed by the boring lamellibranchs *Teredo* and *Teredina*, allies of the modern "ship-worm." *Pyrgula Smithi* and *Xenophora extensa* are noticeable gastropods. *Aporchais Sowerbyi* is a gastropod from Oldhaven Gap. Characteristic of the Woolwich beds are *Corbicula* [*Cyrena*] *dalwicensis*, *Corbula regulbiensis*, *Pithardella Rickmani*, a freshwater shell, and *Ostrea bellovacina*, of which a fine mass is exhibited. From the Thanet Sands come *Cyprina Morrisi*, *Pholadomya cuneata*, and *Meretrix orbicularis*. In the middle of the Gallery stands a slab of "Bognor Rock" from the London Clay of Bognor, largely composed of shells or the casts of shells of *Cardita Brongniarti*, *Glycymeris* [*Arcinava*] *brevirostris*, *Volsella* [*Modiola*] *deponis*, *Voluta deauidata*, *Pyrgula Smithi*, *Natica hantonicensis*, and the annelid *Vermetus boguoriensis*. Other masses of the same age from Fareham, Hants, are placed on the wall; one is full of shells of the lamellibranch *Pinna affinis*, the other (Plate V.) contains in addition *Glycymeris brevirostris* and the smaller *G. decussata*.

Cretaceous. This series is rich in specimens described by G. A. Mantell, Samuel Woodward, James Sowerby, J. de C. Sowerby in Dixon's "Geology of Sussex," H. Woods, and others. Except those from the estuarine or lacustrine deposits of the Wealden series, all are marine. First come the shells from the Upper and Middle Chalk and Chalk Rock, in other words from those zones that are of **Senonian** and **Turonian** age. Among these the lamellibranchs of the genus *Inoceramus* are conspicuous and their disintegrated shells enter largely into the composition of the Chalk: *I. Cucieri* may attain a width of 18 inches, some large pieces of its hinge are shown; *I. labiatus* gives its name to a Turonian zone; the original specimen of the widely distributed *I. Crippsi* is of historical importance. *Spondylus spinosus* with the long spines well preserved (Fig. 70), and the five-ribbed fan-shell *Neithea quinqucostata* (Fig. 71 a), are characteristic of the Upper Chalk; the gastropod *Pleurotomaria perspectiva* is Turonian. Here too are tubes of *Teredo amphibæna*, and several specimens of the curious *Radiolites Mortoni*, one of the Rudistæ (see p. 143).

Following on these are shells of **Cenomanian** age, coming from the Lower Chalk, Upper Greensand, and Chalk Marl. Here may be noted the cocks-comb oyster *Alectryonia carinata*, the scollops *Chlamys Beaveri* and *C. asper*, of which the latter gives a name to the "Pecten asper zone," the

Gallery
VIII.
Centre
and
Table-case
5.

Between
Wall-cases
3 & 4
and
4 & 5.

Table-cases
6 9.

Table-case
6.

Wall-case
5A.

Table-case
6.

Table-cases
6 & 7.

Gallery
VIII.

four-ribbed *Neithra quadricostata*, and *Syncyclonema* [*Pecten*] *orbicularis*. Among the Grey Chalk fossils from Folkestone, *Rostellaria Pricci* and *Aporrhais Mantelli* are remarkable.

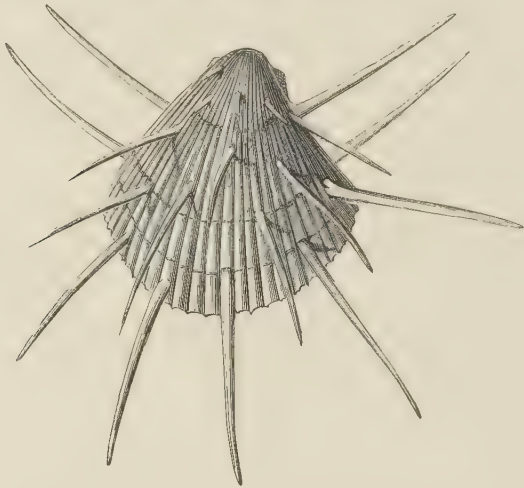


FIG. 70.—A Lamellibranch shell, *Spondylus spinosus*, common in the Senonian Chalk of England. Natural size.

Table-case
7.

A beautiful series of silicified shells from Blackdown and Haldon in Devonshire, a set from the Red Chalk of

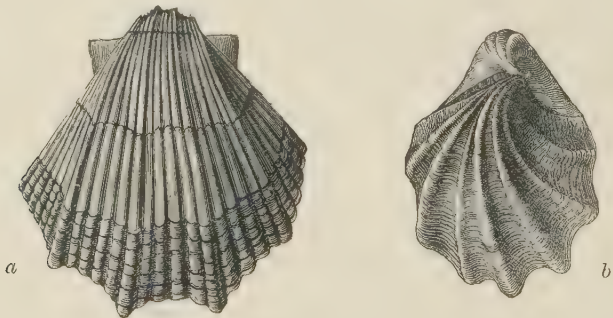


FIG. 71.—Cretaceous Lamellibranchs. *a*, *Neithea quinquecostata*, common in Senonian Chalk; *b*, *Actinoceramus sulcatus*, from the Gault. Natural size.

Hunstanton in Norfolk, and another from the Cambridge Greensand, are all of **Albian** age. Of the same age are the shells from the Gault clay of Folkestone, of Black Ven,

Charmouth, and of Okeford Fitzpaine also in Dorset, all which are on the other side of the Case. Among the Gastropods the Aporrhaidæ with their winged lips and the Scalariuidæ with their transverse ribs furnish the most striking forms. Among Lamellibranchs one may notice species of *Actinoceramus* (Fig. 71 b), *Trigonia*, *Cucullæa*, *Liopistha* [*Thetis*], *Thracia*, *Pinna*, *Perna*, and *Protocardia*.

Gallery
VIII.

During the **Aptian** age was deposited the Lower Greensand of Hythe, Sandgate, and Faringdon. Here are casts of the borings made by *Lithodomus* and *Pholas*. *Pleurotomaria gigantea*, *Alectryonia macroptera*, and *Toucasia Lonsdalei* are noteworthy forms. The last is a representative of the Diceratidæ (see p. 143).

Table-case
8.

The **Barremian** or **Urgonian** age is represented in the South of England by the marine Atherfield Clay of the Isle of Wight and the brackish-water Punfield Beds of Dorset, both of which belong to its lower division. *Exogyra sinuata* was then a common oyster; among the shells exhibited one has been cut through to show its great thickness in old age. The long-hinged *Perna Mulleti* occurs in quantities in a special layer at Atherfield. Here are also shown the elongate *Gervillia anceps*, with species of *Trigonia*, *Sphaera*, *Protocardia*, *Cyprina*, and *Astarte*, and, among the Gastropods, *Ceratospion* [*Aporrhais*] *Fittoni*, and *Vicarya Pizcuctana*.

Table-case
8.

Next come fossils from various rocks in the east of England: the Speeton Clay of Yorkshire, the Tealby Series, and Claxby Ironstone, of Lincolnshire, all which correspond partly to the Barremian and partly to the preceding **Neocomian** Age. Among the more interesting lamellibranchs are *Exogyra subsinuata* (= *E. Couloni*), *Trigonia ingens*, and the large *Camptonecles* [*Pecten*] *cinctus* from the Claxby Ironstone and *Cucullæa donningtonensis*. The Lincolnshire formations run over into the next Case, and are followed by fossils from the Wealden of Sussex and the Isle of Wight. The name **Wealden** is applied to a series of freshwater and estuarine formations deposited mainly during the Neocomian Age, and perhaps beginning at the end of the Jurassic Epoch. Among river-shells are examples of *Unio*, including the type-specimen of the large *U. caldensis* from Sussex and the Isle of Wight, also the oldest *Anodonta* known—*A. Becklesi* from the Hastings beds. In the middle of the Gallery is a polished slab of Petworth or Sussex Marble, composed of the shells of a freshwater snail, *Viviparus*

Table-case
8.

Table-case
9.

Gallery
VIII.

[*Paludina*] *fluxiorum*, in a greenish calcareous cement. The marble occurs in layers, from a few inches to a foot in thickness, and is used for chimney-pieces, slabs, and columns. It may be seen in Canterbury, Chichester, and Salisbury Cathedrals, York Minster, Westminster Abbey, and the Temple Church. A similar stone is found at Bethersden in Kent. Other bands of limestone, often red, are full of *Corbicula* [*Cyrena*] *media*. *Pleuroccra strombiformis* (= *Potamidites carbonarius*) is also noticeable.

Table-case
9.

Further west in the same great estuary were deposited the **Purbeck Beds**, the uppermost of which are by some geologists regarded as Cretaceous, while the lower are Jurassic. They extend from the Isle of Purbeck in Dorset to Brill in Buckinghamshire, and are found also at Brightling and Pounceford in Sussex. A small set of shells from them is shown, and in addition to some species already observed in the Wealden, contains *Corbicula* [*Cyrena*] *parca*, *Unio Martini*, *Physa Bristovi*, and the marine form *Mytilus Lyelli*. One of the characteristic beds is the Purbeck Marble, very like the Petworth Marble, and another is the Cinder Bed composed of *Ostrea distorta*, an oyster that probably owes its peculiar shape to brackish-water conditions.

Between
Wall-cases
6 & 7.

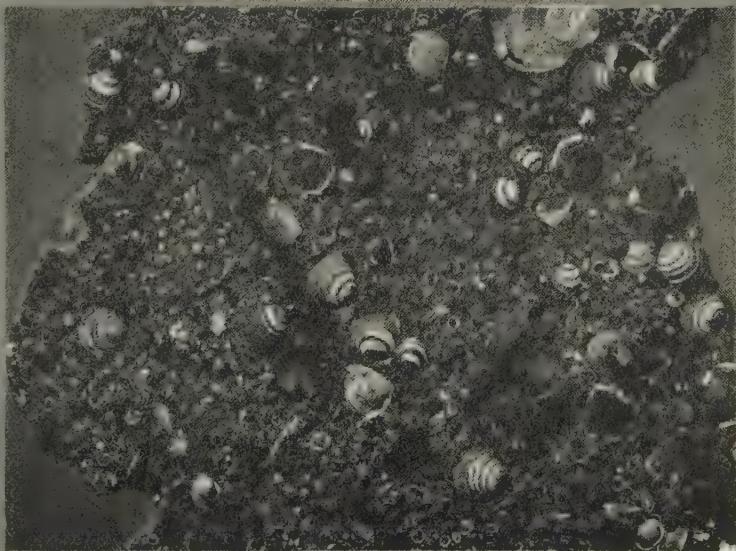
Table-cases
9-14.

Jurassic. Leaving the estuarine formations of intermediate and uncertain age, we return to the marine series, exhibited under a number of stratigraphical groups, which will be taken in order, beginning with the highest. Many of these British Jurassic specimens in the Museum are of historical importance, having been described and figured by J. Sowerby, J. Phillips, Morris & Lycett, S. Stutchbury, R. Damon, W. H. Hudleston, J. F. Blake, and others.

Between
Wall-cases
5 & 6.

Table-case
9.

The Portland Oolite, from which is derived the name of the **Portlandian** Age, is worked for building stone in Dorset and Wiltshire. Two slabs of the hard Portland stone are shown; one of them contains shells of the lamellibranchs, *Perna Bouchardi* and *Chlamys* [*Pecten*] *lamellosus*; the other is almost entirely composed of shells of *Cerithium concavum*. In the middle of the gallery is a large block of the "Roach-bed," which is full of hollows, whence the shells have been dissolved by percolating water, leaving behind impressions and internal casts of the following species: *Trigonia gibbosa*, *Chlamys lamellosus*, *Ostrea expansa*, *Lucina portlandica*, and *Protocardia dissimilis* among lamellibranchs; *Natica elegans* and *Cerithium portlandicum* among gastropods. All these shells may be better studied in the Table-case, as well as



FOSSIL SHELLS.

Trigonia in Corallian rock from Weymouth.
Part of a Shell-bank in London Clay at Fareham, Hants.

[To face p. 135.]

Pterocera oceani, *Pleurotomaria rugata*, *Sowerbya Dukei*, *Astarte rugosa*, and many species of *Trigonia*. Note also the large borings of *Lithodomus*.

Gallery
VIII.

The shells of the **Kimmeridge** Clay are mainly from Weymouth, Dorset; Wootton Bassett, Wilts; the neighbourhood of Oxford; and Hartwell, Bucks. The following are noteworthy: the large *Pleurotomaria reticulata*, the D-shaped *Ostrea deltoidea*, the common and characteristic *Erygyra virgula*, *Gryphaea dilatata* with its thickened hinge, well shown in sections, a *Gryphaea* with a supposed pearl, *Protoearbia* [*Cardium*] *striatula*, *Astarte hartwellensis*, various *Trigonias*, *Goniomya literata*, and *Thracia depressa*. A slab of Kimmeridge Clay filled with *Ostrea lucrinsecula* is on the wall, and below it is the fine block of Coralline Oolite with over 110 shells of *Trigonia clavellata* figured in Damon's "Geology of Weymouth" (see our Plate VI.).

Table-case
10.

Between
Wall-cases
6 & 7.

The Coral Rag and Calcareous Grit are the chief British rocks formed during Sequanian or **Corallian** time; they stretch across England, with occasional breaks, from Weymouth to Buckinghamshire, reappearing in Yorkshire, and are rich in fossils. Among the gastropods are *Bourquetia* [*Phasianella*] *striata*, *Pseudomelania heddingtonensis*, *Nerinaea Goodhulli*, and a spiny winkle *Littorina muricata*. Lamellibranchs are represented by *Alectryonia gregaria*, *Chlamys vimineus*, *Ctenostreon pectiniformis*, *Mytilus pectinatus*, *Trigonia triquetra*, and many others. The numerous borings of *Gastrochaena* and *Lithodomus* in the coral masses bear witness to a shallow sea. It is interesting to contrast the richness and variety of the molluscan fauna that lived in the Corallian sea with the comparatively few species found in the clays above and below.

Table-case
10.

The clay below is the **Oxford Clay**, well developed in Oxfordshire, and forming a more continuous band across England from Dorset to Yorkshire than do the Corallian limestones. Within this tract the fossils are entirely marine, and those exhibited come chiefly from Weymouth, Christian Malford and Chippenham in Wiltshire, and Scarborough. The delicate character and shelly constitution of the Wiltshire specimens contrast with the coarser and stony appearance of the others. Characteristic forms are *Alaria trifida* with its long processes, the delicately spined *Spinigera spinosa*, *Nucula ornata*, *Volsella* [*Modiola*] *cuneata*, and *Pleuromya recurva*. Under *Ostrea* and *Gryphaea* are to be seen shells that have grown upon *Trigonias* and an ammonite and have assumed

Table-case
11.

Gallery
VIII.

their ornament. Adjoining these are shells from the Kella-ways Rock, a brownish sandstone at the base of the Oxford Clay, giving a name to the **Callovian** Age. Among these are *Gryphaea bilobata* with a curious fold on its side, *Isocardia minima*, and *Goniomya V-scripta*.

Table-case
11.

The shells of **Bathonian** age are arranged under the formations from which they come. First are those from the widely distributed rubbly limestone called **Cornbrash**, which has yielded the scaphopod *Dentalium annulatum*, the gastropods *Bulla undulata*, *Pseudomelania vittata*, and the lamellibranchs *Chlamys* [*Pecten*] *vagens*, *Lima duplicata*, *Pseudomonotis* [*Avicula*] *echinata*, and several *Trigonias*. Many of the specimens are figured in Blake's "Monograph of Cornbrash Fossils." There are very few shells from the **Forest Marble**, but among them is a fine example of *Trigonia detrita* figured by Lycett. In the equally small series from the **Bradford Clay**, one may notice a set of

Table-cases
11 & 12.

Oxytoma [*Avicula*] *costata*. The **Great Oolite** shells are mostly from the Oolitic freestone. Here is the type-specimen of *Pterocera Wrighti*, a fine winged shell; then several species of *Purpuroidea*, among which *P. morrisea* with its heavy spines is conspicuous; several limpets, *Patella*, testify to the rocky nature of the sea-floor; *Nerita rugosa* seems to show bands of colour, and such are still more evident in a large form of *Natica*. Among lamellibranchs one may note *Lima cardiiformis*, *Pteroperna costatula*, *Pinna ampla*, *Parallelodon* [*Macrodon*] *hirsonensis*, and the massive *Pachyrisma* ("thick support") *grande*. The Stonesfield Slate yields *Trigonia impressa* and *Pinna cuneata*. The small series from the **Fuller's Earth** includes *Volsella* [*Modiola*] *imbricata* and *Ceromya plicata*.

Table-cases
12 & 13.

Next come shells from the variable series of marine limestones known as the **Inferior Oolite**, deposited mainly in **Bajocian** time. The chief localities in the south-west of England here represented are Dundry near Bristol, Half-way House near Yeovil, Bradford Abbas, and Leckhampton Hill near Cheltenham. These have yielded a fine series of *Pleurotomaria*, many species of *Amberleya*, *Pseudomelania*, *Purpurina*, *Delphinula*, *Cerithium*, *Cirrus*, *Nerinea*, *Alaria*, and other gastropods. Certain species of *Amberleya*, *Cerithium*, *Onustus*, and *Neridomus* acquired an interest a few years ago from their resemblance to some shells now living in Lake Tanganyika; but it is not now imagined that the animals themselves had the same structure. Similar

Gallery
VIII.

repetition of outward form at different epochs has already been noticed among the Brachiopoda (p. 115). Among lamellibranchs from the same rocks are *Alectryonia*, *Lima*, *Ctenostreon*, *Inoceramus*, and the large *Trichites* with its thick shell, a favourite haunt of *Lithodomus*, as various specimens show. Another specimen shows a *Lithodomus* burrow in the floor of the Oolitic sea, here formed of black Carboniferous Limestone. Then follow many species of *Trigonia*, *Astarte*, *Pholadomya*, *Ceromya* and other genera. Among all these specimens may be noticed others from the Ironstone of Duston, Northamptonshire, and from the Collyweston Slate. In Yorkshire the Bajocian series includes beds of estuarine origin, furnishing such forms as *Unio* and *Anodonta*.

Table-case
14.

The lamellibranchs from the **Lias** are arranged under the three divisions of that marine formation: the Upper, of Toarcian age, the Middle, of Pliensbachian, and the Lower, of Sinemurian. Here one should notice *Leda ovum*, which gives its name to a horizon in the Upper Lias, *Volsella* [*Modiola*] *scalprum* from the Middle and Lower Lias, the very familiar *Gryphæa incurva*, and the equally massive *Hippopodium ponderosum*, both from the Lower Lias (Fig. 72).

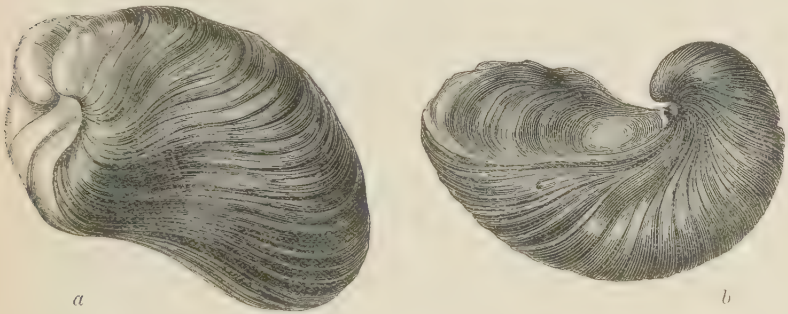


FIG. 72.—Lamellibranch shells from the Lower Lias. *a*, *Hippopodium ponderosum*; *b*, *Gryphæa incurva*. Natural size.

Orytoma [*Aricula*] *cygnipes*, from the Cleveland ironstone beds of Yorkshire is a fine shell. The gastropods are all placed together, since they are few in number, and nearly all comprised within three genera: *Eucyclus*, *Cryptacna*, and *Pleurotomaria* (Fig. 73). This last contains some large shells, those of *P. anglica* being most numerous.

Trias. The Mollusca come chiefly from the **Rhaetic**

Table-case
14.

Gallery
VIII.

beds of Beer, in Devonshire, and Westbury, near Bristol. *Avicula contorta* is the best known, as giving a name to a widely distributed horizon of Rhaetic Age. Like the Rhaetic shells generally, it is relatively small, perhaps in consequence of brackish water. *Monotis decussata* and *Chlamys valoniensis* are also important. There is a small but interesting series from the Keuper Marls of Warwickshire. The Conchylilian Age has no shell-bearing rock in this country.

Table-case
14.

Permian. This Epoch is represented by marine shells from the Magnesian Limestone of Durham and the red marls near Manchester. Note *Monotis speluncaria* and *Byssocarea striata* from the former, and the tiny *Rissoa* and *Turbo* from the latter. *Bakewellia antiqua* comes from both localities, and from Tyrone as well.

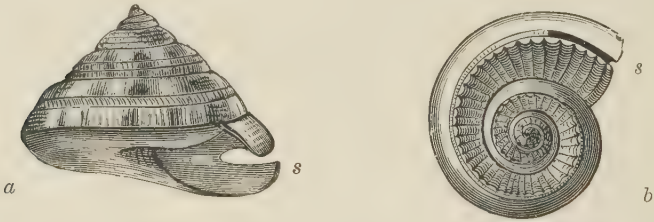


FIG. 73.—Recent and fossil shells of *Pleurotomaria*. *a*, *P. Quoyana*, now living in the West Indies; *b*, *P. platyspira* from the Middle Lias of France. The slit *s* receives the projecting anus, and, as the shell grows forward, is filled up by shell-substance. Both figures are less than natural size.

Table-case
15.

Carboniferous. The shells of this Epoch come mainly from the Coal Measures and the Mountain Limestone, the rocks of Middle Carboniferous or Moscovian age having yielded few mollusca in this country. The Coal Measures, though largely of fresh or brackish water origin, contain many marine bands; the Lower Carboniferous rocks are all marine. The fossils have not here been separated according to age or rock or habitat. It will, however, be noticed that the Coal Measure fauna, and particularly the freshwater elements in it, occur among the lamellibranchs, whereas the gastropods are almost all from the Mountain Limestone. Among the Coal Measure fossils are many described by Sowerby in Prestwich's classical memoir on Coalbrookdale, and many described by Dr. Wheelton Hind in the Monographs of the Palaeontographical Society. The fresh-water forms include *Anthracomya* and *Carbonicola* [*Anthracosia*]

(Fig. 74 *a*), which had a very wide distribution during this Age (Ouralian). Marine forms are *Ariculopecten papyraceus*, *Pinna costata*, and *Nuculana attenuata* from Scotland. Among lamellibranchs from the Mountain Limestone are the peculiarly shaped *Conocardium* and various species of *Cardiomorpha*. *Posidonomya Becheri* is widely distributed in the Lower and Middle Carboniferous, often occurring in abundance and giving its name to certain beds in this country and on the Continent (Fig. 74 *b*). The gastropods of Lower Carboni-

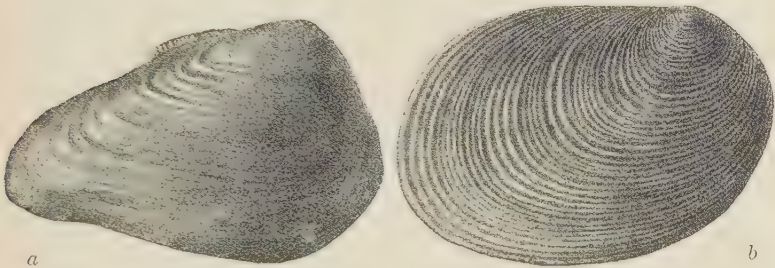


FIG. 74.—Carboniferous Lamellibranchs. *a*, *Carbonicola* [*Anthracosia*] *robusta*, Upper Coal Measures; $\frac{2}{3}$ natural size. *b*, *Posidonomya Becheri*, Middle Carboniferous, North Devon; natural size. (Table-case 15.)

ferous age contain many genera not hitherto noticed; among these *Macrocheilus*, the loose-coiled *Phanerotinus*, *Euomphalus*, and the wide-mouthed *Bellerophon* are conspicuous; a large shell of *Naticopsis* retains the operculum, lofty-spired forms are represented only by *Marchisonia* and *Loxonema*; *Mourlonia* is a fore-runner of *Pleurotomaria*; *Platyceras* [*Cupulus*] often occurs on the ventral surface of crinoids, living on the food-particles that they reject.

Devonian. During this epoch the sea existed where now are found fossils similar to those found in the Devonian limestones and slates of the Continent. The rocks that were at the same time being deposited over the rest of the British area are for the most part known as Old Red Sandstone, and seem to have been formed in lakes or estuaries. Evidence of this is furnished by the large shells related to the modern fresh-water mussel, and called *Archæonodon Jukesi*. Specimens of this, the oldest non-marine lamellibranch as yet known, come from rocks of Upper Devonian age in Northumberland, Monmouth, and Kiltorcan in S. Ireland. The marine forms from the south-west of England are mostly Middle Devonian gastropods from the collections of the late W. Vicary and

Table-case
15.
Between
Wall-cases
7 & 8.
Table-case
15.

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VIII.

J. E. Lee, and have been described by the Rev. G. F. Whidborne in the Monographs of the Palaeontographical Society. Here are most of the genera already observed in the Carboniferous series. Among lamellibranchs *Cardiola retrostriata* is important to the stratigrapher.

Table-case
16.

Silurian. The Ludlovian Age is represented by fossils from Ledbury, Ludlow, and Kendal, the Wenlockian by fossils from Dudley and Benthall Edge, the Valentian by a few Bellerophons from the Llandovery beds. In addition to the Palaeozoic genera already mentioned, one may see here *Pterinea* (Fig. 75 b), *Orthonota*, and *Grammysia* among the common lamellibranchs. The gastropods include numerous forms allied to *Euomphalus*, one of them, *Polytropina*, preserving the operculum, also the slightly curved *Ecculiomphalus*, and *Trematonotus* (Fig. 75 f), the "pierced back" ally of *Bellerophon*. The Amphineura are represented by *Helminthochiton*.

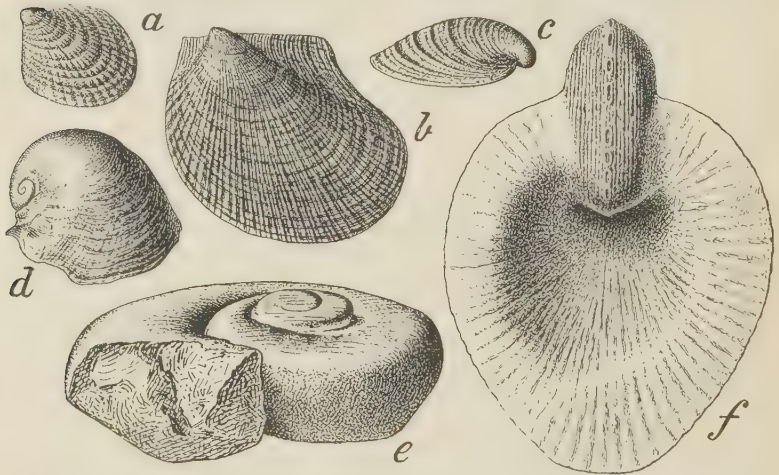


FIG. 75.—Lower Palaeozoic Lamellibranchs and Gastropods. *a*, *Cardiola interrupta*; *b*, *Pterinea Danbyi*; *c*, *Bellerophon cambriensis*, a reconstructed side view; *d*, *Platyceras* [*Acroculia*] *haliotis*; *e*, *Maclurea Loganii*, the type-specimen; *f*, *Trematonotus dilatatus*. *a*, *b*, *d*, and *f*, are Silurian from the Wenlock beds of Dudley; *c* is Ordovician, from the lower Llandeilo of Ayrshire; *e*, Cambrian, from the Upper Festiniog beds of Dolgelly. *a* and *c* are nat. size; *b*, *d*, *e*, *f*, $\frac{1}{2}$ natural size. (Table-case 16.)

Table-case
16.

Ordovician. The rocks of this Epoch, formerly classed as Lower Silurian, have furnished molluscan fossils from the Caradoc, Llandeilo, and Arenig divisions. Those exhibited

come mostly from Wales and Shropshire, but there are a few from Tyrone, and a fine series of the loosely-coiled *Maclurea* from Scotland (Fig. 75 e).

Cambrian Mollusca are few, and in Wales, where the rocks are exposed, the shells are poorly preserved. *Glyptarca primavera* and *Bellerophon cambriensis* (Fig. 75 c) may be noted.

In a special Table-case at this end of the Gallery are placed together the British and foreign specimens of **CONULARIDA**. These, which are almost exclusively Palaeozoic, are sometimes regarded as forming a Sub-Order of Pteropoda; but now that the origin of the Pteropoda from Opisthobranch Gastropoda appears certain, this view is scarcely tenable. Some of the simplest forms are found in the Lower Cambrian of North America, and of these *Salterella*, *Helenia*, and *Hyalithellus* are exhibited. They are thick-walled tubes, straight or bent, smooth or striated, ending in a point, and are generally placed in a family with *Torelletta* from Sweden, which has a shell of phosphate of lime. *Salterella* has also been found in West Australia, and *Hyalithellus* occurs in Ordovician rocks. The Devonian *Coleoprion* is probably an allied form. The shell of *Hyalithes* [*Theca*] and a few similar forms is composed of carbonate of lime, is conical, straight or curved, triangular, elliptical, or flattened in cross section. Its surface is smooth or striated, and it is closed by an operculum. The narrow end of the shell is often divided by cross partitions. Species of this genus lived throughout the Palaeozoic Era, but were most abundant in its earlier half. The shell of *Tentaculites* is an elongate cone, ornamented with rings. It often begins in a small bulb, and the earlier portion may be partitioned as in *Hyalithes*. Its thick wall is composed of two layers.

The genus abounds in Silurian and Devonian rocks, often being the chief constituent of certain beds. *Conularia* is the most widely distributed in space and time, and contains the greatest number of species and the largest individuals of all Conularida. The shell is elongate and four-sided.

Each face is divided lengthwise by a groove (Fig. 76e) and

Gallery
VIII.

Table-case
16.

Central
Case A7.

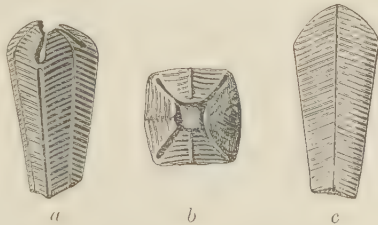


FIG. 76.—*Conularia quadrisulcata*, Coal Measures of Coalbrookdale. The lower end is broken off. *a*, side view; *b*, aperture seen from above; *c*, back view.

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ornamented with parallel ridges, which slope upwards toward this groove. The margin of the shell opening is folded inwards (Fig. 76 *b*). A few specimens of Cambrian age are shown. The largest are Ordovician, those from the Grés de May in Calvados being noteworthy. Several species occur in Silurian rocks, and there will be noticed some specimens well preserved in nodules from the British Coal Measures. Some from the Permo-Carboniferous rocks of New South Wales are exhibited. A single species is also found in the Trias and in the Lias.

We return now up the side of the Gallery, taking the Wall-cases with shells from **foreign localities** in reverse order.

Wall-cases
8 & 9.

Palaeozoic. On the bottom slope of Case 9 are fossils of Cambrian, Ordovician, and Silurian age, mainly consisting of the Barrande Collection from Bohemia. Among the few North American specimens is *Megalomus*, which forms thick banks in the Guelph Limestone. Devonian fossils, mostly from Germany, follow on the same slope. The irregularly-shaped *Platyceras* [*Acroculia*] *Protei* from Mayenne is worth notice. The middle slope contains the Carboniferous shells, among which those of the De Koninck Collection from Belgium are the most numerous. Here the *Chiton* claims attention. These are succeeded by a series from the Permo-Carboniferous rocks of Tasmania and New South Wales, many described in Strzlecki's book on the latter colony (1845). Then come Permian fossils from the Zechstein of Saxony, with a few from Africa, among which is a specimen of a freshwater Lamellibranch collected by Henry Drummond on the N.W. shore of Lake Nyassa.

Wall-case
9c.Wall-case
9.Wall-case
8.Wall-cases
9-5.Wall-case
9, top slope.Wall-case
8.Wall-case
7.

Mesozoic. The **Trias** begins with a series of marine lamellibranchs from the Malay Peninsula, described in the Proceedings of the Malacological Society (London, 1900); the next is the valuable collection from St. Cassian in the Tyrol, formed and described by A. v. Klipstein. The **Lias** of Germany and Northern France is fairly well represented; among the gastropods is also a set of *Lithotrochus Humboldti* from Peru. Wall-case 7 contains the shells of **Oolitic** (Aalenian to Portlandian) age. At the end are placed three interesting series recently described: from Singapore (Geological Magazine, 1906); from Borneo (Proceedings of the Malacological Society, 1903); and from Madagascar (Quart. Journ. Geological Society, 1889 and 1895). On the bottom slope is a fine series from the Bajocian and Bathonian rocks of Normandy agreeing closely with that

from British localities of corresponding age; the large *Pleurotomaria Proteus* and the great limpet *Patella Tessoni* cannot fail to attract attention. The shells on the middle slope range from Callovian to Corallian, and among the lamellibranchs *Diceras* with its two curly horns should particularly be noticed. Shells from the Solenhofen lithographic stone and other rocks of Kimmeridgian age, with many from the Portlandian, occupy the top slope; most are from French localities.

The Cretaceous series from Neocomian to Cenomanian comprises specimens from all quarters of the globe. The most remarkable are the Diceratidae and their descendants. *Diceras* and *Toucasia*, already noticed, are fixed to the sea-floor by one valve, just as is their more ordinary relation *Chama*. In them, however, this fixed valve becomes very long, and is often twisted, while the other valve is smaller and may be reduced to a simple lid, as in *Requienia*. In *Monopleura* and *Caprotina* it will be seen that the fixed valve is less twisted, and that it grows upwards like a cup-coral. Like a coral, too, its lower part is often cut off by partitions. The likeness to a coral is still greater in *Hippurites*, of which a simple form is on the bottom slope, and more complicated forms on the top slope. Here too is *Radiolites*, with a massive shell-wall broken up into cubical cavities. Meanwhile the other valve has become a stout lid with great projections inside, presumably for the attachment of muscles. The **Rudistae**, as these later types are called, reach their acme in Turonian and Senonian times with marvellous forms whose true nature must for ever have remained a mystery had we not been able to trace their gradual evolution. In Southern Europe and in the East and West Indies (e.g. *Barrettia*) they formed reef-like masses, now known as Hippurite Limestone. The remainder of the Upper Cretaceous Mollusca are in Case 5A, and adjoining are specimens of *Inoceramus expansus* from S. Africa.

Tertiary. The very complete series from the Paris Basin has an added interest from the fact that most of the specimens were purchased from the eminent fossil conchologist, G. P. Deshayes. The Eocene shells are closely allied to those found in England, but are better preserved, and the species are more numerous. The map showing the formations and localities is taken from "The Eocene and Oligocene Beds of the Paris Basin," by G. F. Harris and H. W. Burrows (London, 1891), a work that gives also a

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6.

Wall-case
5B.

Wall-case
5A.
Between
Wall-cases
4 & 5.

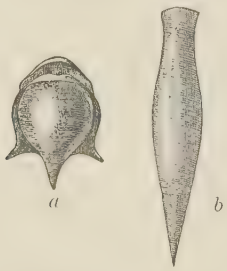
Wall-cases
4-1.

Between
Wall-cases
3 & 4.

Gallery VIII.

full list of the Mollusca. Below it are fine specimens of the Middle Eocene *Campanile* [*Cerithium*] *giganteum*, while in Case 4 is a longitudinal section of the same fossil, showing the shelly pleats upon the columnella. Next come the Tertiary shells from Bordeaux, from Muddy Creek, Victoria, and from South Australia. Pliocene shells from Italy are followed by Post-Pliocene shells from raised beaches in Florida, Australia, and elsewhere. A "Catalogue of the Australasian Tertiary Mollusca," by G. F. Harris, was issued by the Trustees in 1897. On the bottom slopes of Wall-cases 1-3 are temporarily placed small series recently acquired: Eocene shells from Northern Nigeria; Eocene shells from Somaliland; Miocene shells from the Azores and from Malta; Post-Tertiary and Tertiary shells from the region of the Dardanelles; Tertiary shells from Patagonia; Post-Tertiary shells from Angola, W. Africa; and Tertiary shells from Alaska. All the preceding series are marine, but there is also a series of Post-Pliocene shells of estuarine character from the Pampean formation near Buenos Ayres. Adjoining these is the collection of marine Miocene shells from Maryland, described by Thos. Say in 1824.

- Wall-case 2.
- Wall-case 3.
- Wall-case 2.
- Wall-case 1.



Wall-case 1A.

FIG. 77.—Miocene "Pteropods." a, *Hyalæa tridentata*; b, *Vaginella depressa*.

Finally, next the entrance to the Gallery, is a small representative set of Pteropod shells (see p. 125), mostly from the Upper Tertiary rocks of Italy. Some recent additions to the exhibited series of Mollusca are mentioned in an Appendix (p. 177).

CLASS CEPHALOPODA.

Gallery VII.

A whole Gallery is occupied by fossils belonging to the remaining Molluscan Class, the Cephalopoda (Head-feet). The meaning of this name is obvious to any one considering such well-known **living examples** of these marine molluscs as the octopus, the cuttle-fish, the squid, and the nautilus (Fig. 78), in all of which the mouth is encircled by arms or tentacles, the altered representatives of part of the molluscan foot. Just behind these are the two eyes. The hind-part of the body consists of a rounded or sometimes elongate sack containing the viscera and called the visceral hump. Part

of the skin forms a mantle-fold on the under surface and encloses the gills. In front of the gills another part of the foot is folded together to form a funnel through which the water that has passed into the gill-chamber can be forcibly squirted out. By this means the animal can be driven backwards through the water (Fig. 87). The mouth is armed with strong horny jaws, shaped like a parrot's beak (Fig. 78 *a-c*). The power of locomotion, the concentration of the

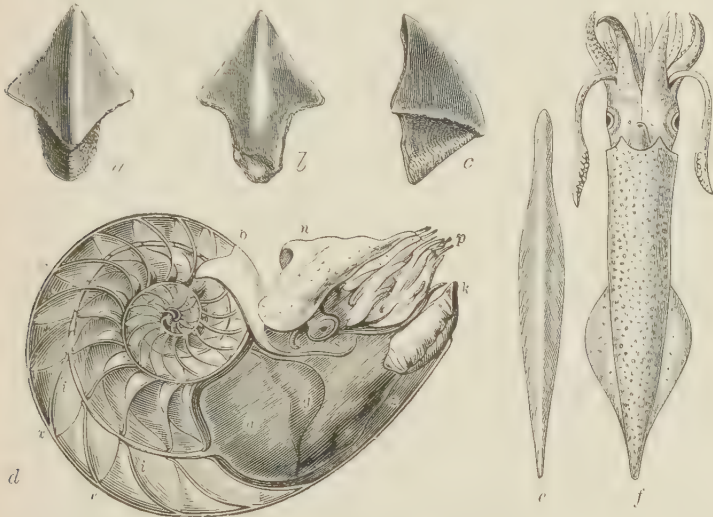


FIG. 78.—Cephalopoda. *a, b, c*, Rhyncholiths, fossil beaks of a nautilus from the Miocene of Malta; nat. size; *d*, the Pearly Nautilus in its shell, part of which has been cut away so as to show the chambers and the siphuncle running through them. On the animal are seen the visceral hump (*a*), the muscle and ring of attachment (*g*), the eye (*s*), the funnel (*k*), the tentacles (*p*), and the hood (*n*). *e* and *f*, the squid, *Loligo*; the shell (*e*) is seen from the back, the animal (*f*) from the under side; *d, e, f*, are much less than natural size.

chief organs in the forepart of the body, and the strong jaws, show that these animals can prey upon others, even on those with hard coverings, and lead one to regard them as more highly developed than the other Mollusca. All these features can be recognised in the exhibited specimens and models of living cephalopods. Further study of these specimens will show certain differences between the forms that have been mentioned. Thus the cuttle-fish, squid, and octopus have rather long distinct arms, and these are furnished with suckers strengthened by horny rims; in the nautilus

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Wall-cases
1 & 2.
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1.

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(Fig. 78 *d*) the arms are represented by short lobes, and these are furnished with tentacles that can be withdrawn into sheaths. The eyes in the long-armed forms are conspicuous and are as highly developed as those of a vertebrate animal; in the nautilus one can detect only a small opening leading into a chamber that acts like the simple optical apparatus known as a pin-hole camera. If the mantle-cavity be opened and the gills exposed, it will be seen that there are four gill-plumes in the nautilus, but only two in the other forms mentioned, and indeed in all other cephalopods now living; for this reason, and in view of the other differences, Sir R. Owen divided the Cephalopoda into two divisions: Tetra-branchia (four gills) and Dibbranchia (two gills). We know that some fossil cephalopods, clearly related to the modern Dibbranchia, had long arms, suckers, and large eyes; but we cannot be certain that all of them had only two gill-plumes. Other fossil shells resemble that of the nautilus, and in some of these cases the animal most probably had four gill-plumes; but in other cases there are no grounds for any such assertion. Therefore Owen's classification is unsuitable for fossil cephalopods.

In order to arrange systematically the large number of extinct cephalopods one must consider chiefly those parts of the animal that can be preserved in the rocks. The beaks, the horny rings of the suckers, and similar structures have already been mentioned (p. 123), as also the fact that some fossils found in very fine clays have preserved even the muscles of the mantle (Fig. 86 *a*). As a rule, however, one finds only the shell, with which most of the Cephalopoda are provided. This shell has in the course of geological time undergone many changes, and has been modified in several directions. It is moreover intimately related to the structure and development of the whole animal, and therefore furnishes an excellent basis of classification.

Table-case
1.

Specimens, models, and drawings have been arranged to show the **history and relations of the cephalopod shell**, and to these attention should first be directed. As in all Mollusca the shell is primitively secreted by the mantle or skin of the visceral hump, and, at its edges, by the backwardly turned folds of the mantle. Originally then the shell follows the shape of the visceral hump, and we may suppose that, in cephalopods older than any which are known to us, it was a somewhat conical cap, not unlike the shell of some uncoiled gastropods. Whether these were

active predatory animals, or whether they were sedentary and possibly attached by the shell, is uncertain. But certain it is that at an early period the hump was drawn out into a long visceral cone, and that the shell acquired a similar shape. Then followed a mode of growth very common in sedentary animals that form a tubular shell, and already observed in corals, worms, bryozoans, and gastropods. The mollusc continued to build up the shell around its opening, and thus formed a long tube. As the animal moved along this tube, the visceral cone was pulled away from the shell-

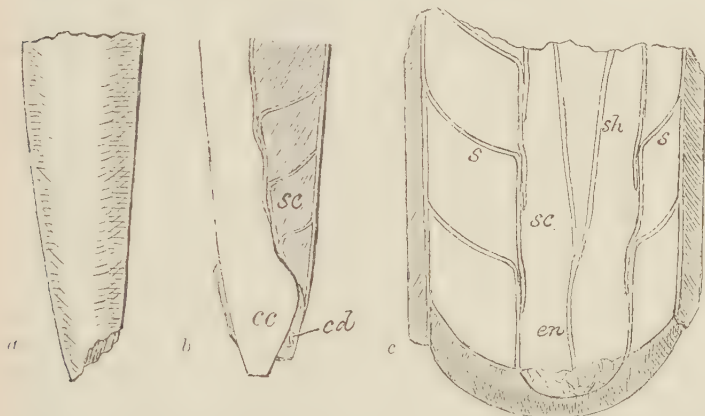


FIG. 79.—Primitive Cephalopod shells: *Endoceras*. *a*, The end of a shell, broken at its apex; *b*, the same cut in half showing the chambers (*sc*), the swollen end of the wide neck-tube (*cc*), and calcareous substance deposited by the end of the siphuncle (*cd*). *c*, Fragment of another shell cut in half, showing the chambers separated by septa (*s*), the large neck-tube (*sc*), a sheath (*sh*), and the endosiphon (*en*). Natural size. (*a*, *b*, after Holm; *c*, after Foord.)

wall; but its skin went on secreting shell-substance, and formed a partition shutting off the space between the visceral cone and the outer wall. In *Endoceras*, here shown (Fig. 79), the visceral cone remained attached to the end of the outer shell, and shrank at a little distance from the apex, so that the partition or septum does not go right across the shell, but shuts off a chamber at the side. Shrinkage then took place a little higher up, and another chamber was formed. By the continuation of this process there arose a series of chambers entirely shut off by septa, and the down-turned portions or necks of these septa formed a long tube in which

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lay the much constricted visceral cone. Examination of polished sections across *Endoceras* and allied forms shows within this septal neck-tube yet another series of structures, called sheaths, and somewhat like a pile of funnels stuck one inside the other (Figs. 79 *c*, 80 *a*). These indicate that, as the animal advanced in its shell, its viscera naturally went with it, and towards the void thus left the walls of the visceral cone were still further sucked in. Thus there tended to

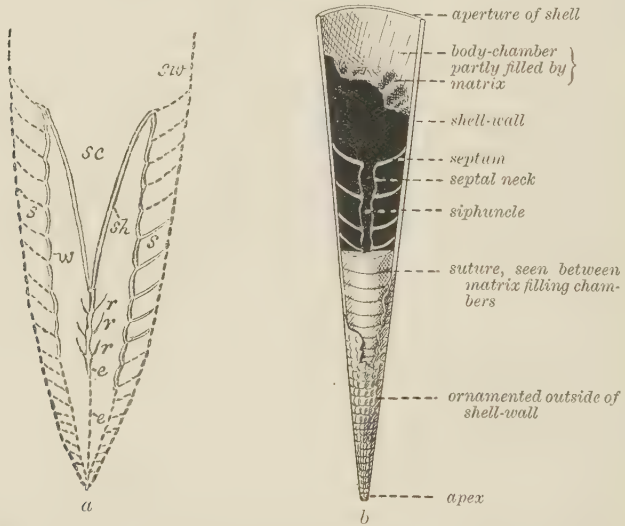


FIG. 80.—Primitive Nautiloidea. *a*, diagram of a section through the middle of *Piloceras*, the dotted lines being reconstructed; *sw*, shell-wall; *s*, chambers divided by septa, whose necks form the wall (*w*) of the wide neck-tube; *sc*, space occupied by visceral cone, the hardened skin of which forms the sheath (*sh*); *r*, remains of similar sheaths; *e*, endosiphon. (After Foord). *b*, *Orthoceras*; in the lower part the shell-wall is preserved; then it is partly removed, showing the filling of rock or matrix; higher up this is cut through, and at the top it is removed, showing the other side of the shell.

arise a narrow and empty tube—the siphuncle. The walls, however, were stiffened with lime and did not completely yield to the suction, so that, when the animal again advanced, the inner layers of the skin were torn away from the outer ones. These inner layers thickened and stiffened in their turn, and the process was repeated. Thus arose the thin tube, sometimes called the endosiphon, and a series of sheaths attached to it.

In *Orthoceras* and similar forms there is an advance on

this mode of growth (Fig. 80 *b*). The shrinkage appears to have been greater from the first, and thus the septa stretch across the conical shell, dividing it into a series of chambers, and leaving only a narrow neck-tube in which there are no sheaths. The part of the shell-cavity in front of the last-formed septum is called the body-chamber, and in it was the main mass of the animal. From the visceral hump, however, proceeded the fleshy siphuncle, passing through each septum to the apex of the shell. The line along which the septum is attached to the shell-wall is called a suture, and in these simple forms passes regularly all round the shell.

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1.

There are numbers of straight shells of this simple type, but those that are the most completely known may be divided into two groups by the presence or absence of a small, more or less globular, initial chamber. This, which is generally separated from the next chamber by a slight constriction, is called the protoconch (first shell) and believed to be the shell of the embryonic cephalopod. It is well seen in some specimens of *Bactrites* (Fig. 81 *k*). Often this protoconch seems to have been lost in the adult, and in its place is seen only a scar or cicatrix denoting its former presence (Fig 81, *c, e, m*).

At an early period in the history of the cephalopod race the shell began to curve, and this curvature increased until the shell was coiled on itself. Such a coiled shell was far more manageable than the long shell of an *Orthoceras*, and was less liable to damage. And so it is found that the long straight shells gradually die out and give place to coiled shells. Now, just as there were two types of straight shells, so were there two of coiled shells: one with a protoconch, as may be seen in models of early goniatites (Fig. 81 *n*); the other without a protoconch, as shown by the model of *Nautilus* (Fig. 81 *a-c*). Further examination of the shells of these two types reveals other differences. The early coiled shells with a protoconch are long, narrow, smooth, with septa usually far apart, and with a long deep body-chamber (Fig. 81 *n*). Those without a protoconch are short, broad, often with a longitudinal ornament, with septa relatively close together, and with a shallow body-chamber (Fig. 81 *a*). In later forms of these two types other differences appear, such as will be realised by comparing an ammonite (which is one of the former series) with a *Nautilus* (Fig. 82). Generally speaking the siphuncle of an ammonite is close to the outside of the coiled shell; the edges of the septa are folded, so that the sutures are compli-

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FIG. 81.—The first-formed portions of various chambered Cephalopod shells. *a, b, c*, *Nautilus pompilius*: *a*, side view; *b*, front view, the apex broken to show siphuncle passing through septa; *c*, apex, showing scar left by protoconch. *d*, a straight shell of Triassic age, with a plug (*p*) at its apex. *e*, a curved Carboniferous nautiloid, *Meloceras*, with scar (*ci*). *f, g, h*, front, side, and upper views of protoconch of an ammonite, *Cosmoceras*. *i*, Protoconch and first chamber of a belemnite. *k*, Protoconch and five chambers of *Bactrites*, the shell partly removed, showing siphuncle. *l, m*, the first two chambers of an allied form from which the protoconch has disappeared, leaving a cicatrix, shown in *m*. *n*, Protoconch and first five chambers of *Mimoceras compressum*, a goniatite. *o*, Protoconch and part of two chambers of *Spirula*, the shell-wall partly broken away. In *g, i, k, o*, the siphuncle is denoted by *si*. *c* is natural size, the rest greatly enlarged. (From Foord & Crick. After Barrande, Hyatt, & Branco.)

cated; the edges of the septa round the siphuncle form a collar projecting towards the opening of the shell; the outside of the shell is ornamented by ribs, folds, or tubercles, radiating from the centre of the coil. In a nautilus, on the other hand, the siphuncle is near the centre of the septum; the edges of the septum are but slightly curved or bent, so

that the sutures are simple; there are backwardly projecting septal necks; the outside of the shell is smooth or slightly ribbed. For these, and other reasons, the cephalopods of which we have been speaking are divided into two Orders: the **Ammonoidea** and the **Nautiloidea**.

Returning now to the straight shells, we shall note that none of those without a protoconch survive the Palaeozoic Era, but that all give place to coiled Nautiloidea. Those with a protoconch, however, do not all give place to Ammonoidea, but some of them begin another line of evolution. In these the chambered shell becomes shorter, and it is believed that folds of the mantle were turned back right over the shell to its very apex, thus affording a

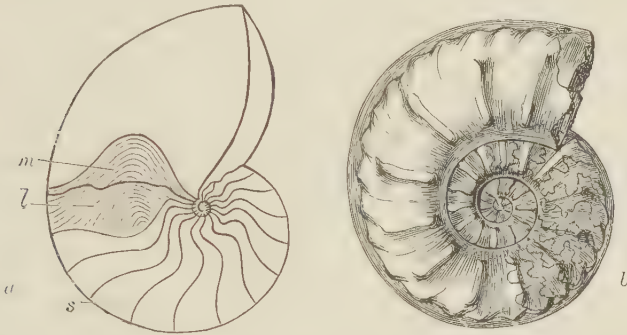


FIG. 82.—A nautilus and an ammonite. *a* is a plaster cast of the inside of the shell of *N. pompilius*, and may be compared directly with the similar internal cast of (*b*) the ammonite. *s*, suture; *m*, mark left by muscle of attachment; *l*, lines left by this mark in its previous positions. Less than natural size.

protection to the shell and to its protoconch. These mantle-folds continued their activity in secreting shell-substance, and so there were deposited outside the apex of the shell a number of layers, forming a solid guard (Fig. 85 *a*). Such forms first appear with certainty in the Trias, e.g. *Aulacoceras*. In these the guard is short, and the chambered shell-cone, when found without it, might be taken for an *Orthoceras*; but it must be noted that the siphuncle is at the margin as in Ammonoidea. It is probable that, like their living descendants, these animals lived an active life and frequently shot backwards by discharge of water from the funnel; thus the value of the guard is obvious. The further history of these forms shows the rise of various

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modifications assisting in one way or another this actively moving life. The main result in all, however, is the enclosure of the shell-cone by the mantle-folds and its reduction in size, so that from being an external protection to the animal it becomes an internal support for the mantle and for fin-like appendages. This does not mean that it becomes an internal skeleton in the true sense of the word; for its relations to the visceral hump always remain the same: it is always outside the true body-wall. Cephalopods in which the shell is thus ensheathed by the mantle constitute a third Order, corresponding, so far as living genera are concerned, to the Dibranchia of Owen. For this Order the name **COLEOIDEA** (sheath-forms) has been proposed; the name **BELEMNOIDEA** has also been used for it, but is more frequently restricted to one of its subdivisions.

In their further history the **Nautiloidea** undergo no changes of importance. It will be well, however, to study the preparations showing some points in their structure. Among these are some internal casts and some portions of shell, showing the scar made by the attachment of the muscles that fix the body to the wall of the shell (Fig. 82 *a*).

The **Ammonoidea** also do not diverge greatly from the general outlines sketched above. They do, however, break up into a number of lines of descent which it has proved exceedingly difficult to unravel. In this study great importance is attached to the foldings of the suture, and some attention may profitably be given to the models showing how the chief types of suture are gradually developed from the simple type of the older forms. A fold of the suture directed towards the opening of the shell is called a saddle, and a fold in the opposite direction is called a lobe. The absence of folding in the earlier sutures characterises forms known as *Ascellati* (unsaddled). Folding, when once started, begins at an early stage in the life-history of each shell, and is manifest even in the suture between the protoconch and the first chamber (Fig. 81 *f-h*). Forms in which this suture has one broad saddle, and in which external lobes and saddles appear gradually in the later sutures, are called *Latisellati* (broad-saddled). Those in which this suture has a narrow saddle in the middle line, bounded on each side by a lateral lobe, and this again by a lateral saddle, are called *Angustisellati* (narrow-saddled). The further developments of these foldings must be studied in the models and specimens, and in professed text-books of palæontology.

The same models show the change from septal necks to the collars characteristic of later Ammonoidea.

Among other specimens shown in this Case are those illustrating the lid or operculum of the ammonite to which, when it was supposed to be an independent shell, the name *Aptychus* was applied (Fig. 83). Some of these specimens preserve the aptychus in its natural position completely closing the opening of the shell. The aptychus consists of two equal halves (sometimes not divided), and there is no good reason for doubting that these were formed as calcifications of that structure which in a nautilus is called the hood (see the preparation of *Nautilus* between Wall-cases 13 and 14).



FIG. 83.—Aptychus of an ammonite.

Returning to the specimens and models that illustrate the structure of the **Coleoidea** or Belemnoida, we study first a belemnite from the Lower Lias of Charmouth that was described by Huxley in 1864 (Memoirs of the Geological Survey). This shows that the guard is small as compared with the size of the whole animal, and that only a small part of the shell-cone is contained within the guard (compare Figs. 84 and 85 *a*). The wall of the body-chamber extends a considerable distance in front of the chambered portion of the shell (or phragmocone) and is known as the pro-ostracum. In front of this is the head of the animal, in which may be seen the beaks; and in front of this again are six arms bearing hooks. Other hookless arms may or may not have been present. Upon this and other specimens is based the exhibited diagram of a belemnite animal. This is seen from the under side, with a part of the skin removed from the middle region and the shell sliced down the middle. In addition to the short hooked arms seen in the fossil just mentioned, are shown two long arms, of which, however, traces have not been found. The funnel is seen emerging in front of the mantle-folds, and on each side of it is an eye. Behind this is the body-chamber, protected on the back by the pro-ostracum, not seen in this view. The viscera are not shown, since nothing definite is known about them, with the exception of a small bag, from which a tube leads forward and opens into the funnel. This bag is filled with a carbonaceous substance which, as known in living cephalopods, can be ejected in the form of a dark ink. It serves to

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obscure the water and protect the animal in its flight from an enemy. A paint made from this ink is called sepia, after the Latin name of the cuttle-fish. The ink-bag is often found in these fossils, and its contents can still be used as a paint. Behind the body-chamber are seen the phragmocone and the guard, and stretching along the sides of the whole shell are expansions of the mantle, forming fins. Belemnites

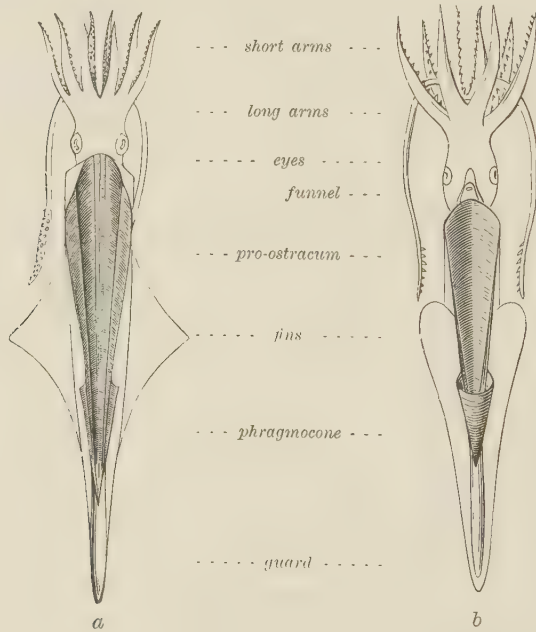


FIG. 84.—Restoration of the animal and shell of belemnites. *a*, back view; *b*, front or under view. (After d'Orbigny.)

having this general structure and a solid guard lived to the close of the Cretaceous Epoch, when they disappeared.

Whereas the Ammonites left no descendants, the belemnites appear to have become changed into other forms. One of these, *Belosepia*, is found in the Eocene London Clay (Fig. 85 *d*). Here the guard has become reduced in size, and the septa stretch in an upward curve from the apex of the shell (corresponding to the belemnite phragmocone) to the front of the pro-ostracum. They are numerous and close together. This form leads to the ordinary *Sepia* or cuttle-fish, of which two glass models are shown. The shell of this

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animal is the familiar cuttle-bone (Fig. 85 *e*). Viewing it from the back one sees at its end a small point (the mucro) corresponding to the guard, and in front stretches a broad shelly plate, like a pro-ostracum. This, however, when viewed from the other side, is seen to be covered by a mass

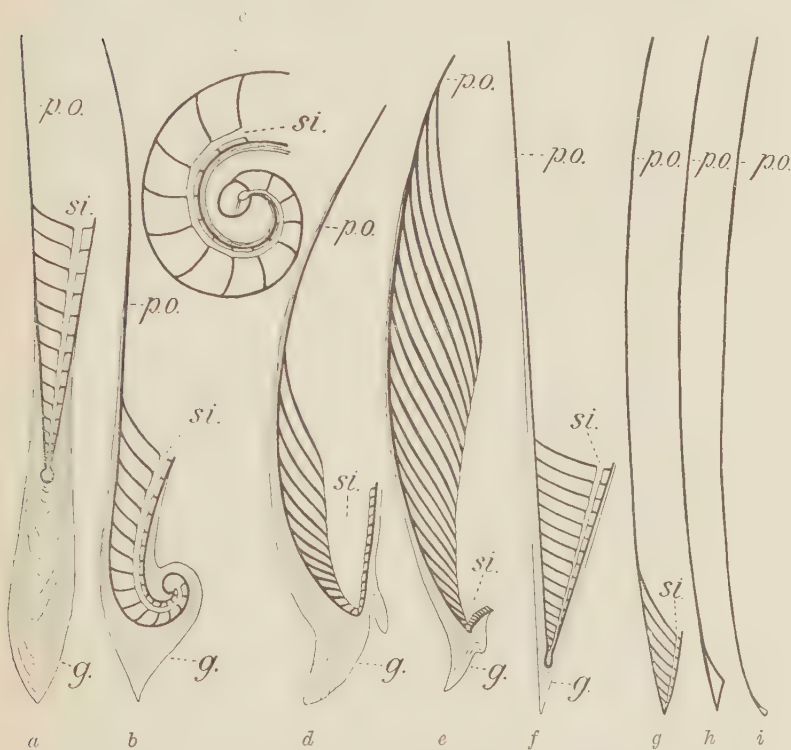


FIG. 85.—The Belemnite and its Descendants. Sections through the middle of the shells, all in the same position. *a*, a belemnite; *b*, *Spirulirostra*; *c*, *Spirula*; *d*, *Belosepia*; *e*, *Sepia*; *f*, *Belemnoteuthis*; *g*, *Conoteuthis*; *h*, *Ommastrephes*; *i*, a squid. In all figures, *p.o.* is pro-ostracum; *si.* siphuncle; and *g.* guard. The shell-wall and septa are represented by thick black lines.

of thin shelly plates, which correspond to the septa more clearly seen in *Belosepia*.

Another Eocene fossil that appears to be descended from the belemnites is *Spirulirostra* (Fig. 85 *b*). In some of the later belemnites may already be observed a shortening of the guard and a curvature of the phragmocone, processes which tend to reduce the unnecessary length of the shell. In

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Spirulirostra the apex of the chambered shell is coiled quite round, and a part of the sheath has come to lie above it; the rest of the sheath is greatly reduced and ends in a sharp point. By further coiling of the shell, by reduction of the pro-ostracum, and by the final disappearance of the guard, was produced the coiled shell of *Spirula* (Fig. 85 *c*). This is very like a shell of the earlier coiled Ammonoidea, but the siphuncle is on the inner side of the coil, the septal necks

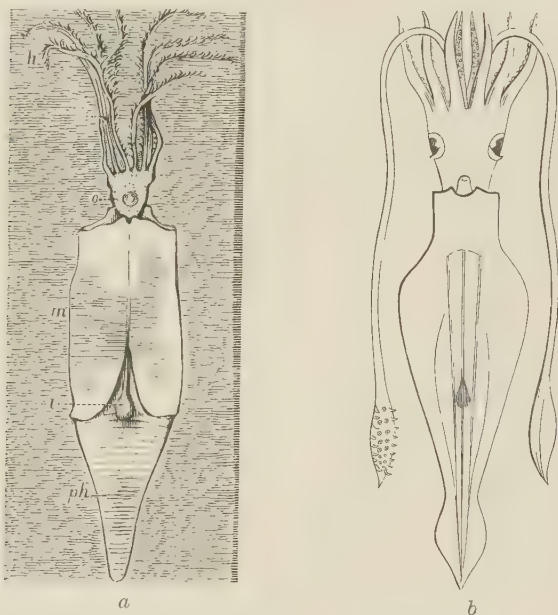


FIG. 86.—Cephalopods with thin enclosed shell. *a*, *Belemnoteuthis antiqua*, Oxford clay, Wiltshire; showing phragmocone (*ph*), ink-sack (*i*), folds of mantle (*m*), one of the eyes (*o*), and the short arms (*a*) with their hooks (*h*); one-third natural size. *b*, *Dorateuthis syriaca*, Cretaceous, Lebanon; showing shell and ink-sack as though the enclosing mantle were transparent; nat. size.

pass backwards, and the shell is very thin. It is almost entirely enclosed by the mantle.

Meanwhile a distinct line of evolution was progressing. Among the beautifully preserved fossils of the Oxford Clay of Christian Malford is the specimen of *Belemnoteuthis antiqua* described by G. A. Mantell (Fig. 86 *a*). Here are to be seen 10 short hook-bearing arms, the head with its well-developed eyes, the folds of the mantle, the fins, the ink-bag,

and the phragmocone. This last is relatively much wider than in the belemnite and is covered by no solid guard, but by a thin coating of horny substance deposited by the mantle, which is still seen surrounding it (Fig. 85 *f*). The reduction of guard and phragmocone has progressed even further in *Geoteuthis brevipinnis*. A specimen of this from the same rock preserves the 10 very short arms, mantle, and tail-fins, and shows a broad thin shell, such as in the squids and calamaries now living is called a pen, with very little trace of any chambered portion (Fig. 85 *g, h, i*). A similar but narrower pen is found in *Plesiotheuthis prisca*, of which specimens from the Solenhofen Stone are exhibited, one of them with the soft parts also indicated (compare Fig. 86 *b*). These pens should be compared with that of the squid, *Loligo vulgaris*, which is shown beside a glass model of the complete animal (Fig. 78 *c*). Other models of living cephalopods with similar shells are exhibited, but cannot here be discussed. It is enough to realise that in one line of descent of these forms with ensheathed shell the chambered cone, long protected by a stout covering, retained its calcareous and septate nature, while in another line it became horny, and ultimately lost its septa.

There was however another line of evolution, the origin of which is difficult to trace, because one of its conspicuous characters was the complete loss of the shell. Another character was the absence of the long arms, reducing the number to eight. These forms therefore are called Octopoda, in opposition to the ten-armed squids and cuttle-fishes, which have been called Decapoda. Study of the early development of an octopus teaches us that its ancestors must have had a shell, and it seems probable that the loss was due to a reduction like that which took place in the squids, but

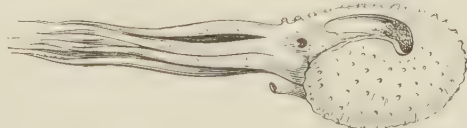


FIG. 87.—Female Argonaut swimming from left to right.

greater in extent. A drawing of the oldest Octopod known is placed in this Case. Beside it are glass models of living species of Octopoda, among which *Argonauta* deserves mention. As shown by the models and by the exhibited specimens, the well-known Argonaut shell is of a different

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nature to that of the other cephalopod shells. It is confined to the female and is secreted mainly by her arms, with which she enfolds her body. Their inner surfaces deposit this paper-like shell, which serves as a protection for the brood. A few examples have been found fossil.

We pass now to the **General Collection**, which is divided into the three Orders, Nautiloidea, Ammonoidea, and Coleoidea or Belemnoidea, the smaller specimens as a rule being in the Table-cases and the larger ones in the Wall-cases. The collection is rich in types and figured specimens, of which a list was published by the Trustees in 1898.

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14.Wall-case
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Order.—**NAUTILOIDEA**. Among the uncoiled Palaeozoic fossils placed in this Order, there are many which increased knowledge will probably cause us to ally with the Ammonoidea or with the Coleoidea. *Endoceras* and its allies, for instance, are generally admitted to be among these (Fig. 79). Many exhibited specimens come from Sweden and the Baltic provinces, where they are common

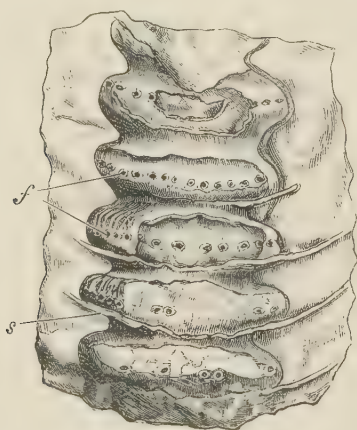


FIG. 88.—*Actinoceras*, the siphuncular structures. A fragment of *A. Bigsbyi*, showing septa (*s*) continuous with the wall of the beaded neck-tube; *f*, openings through the latter to the endosiphon. Natural size. (From Foord.)

Wall-case
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in a reddish-green limestone, of Ordovician age, which, owing to thin layers of shale, splits readily into flagstones. Thus fine specimens may be seen in the pavements of Swedish towns. A fine example, showing the extraordinary length of the shell, is in a framed slab on the wall by the door. Adjoining *Endoceras* are the obscure but deeply interesting specimens of *Piloceras* from the Durness Limestone of Sutherland and Tremadocian beds of Canada (Fig. 80 *a*). Other genera of which the truly Nautiloid character may be questioned are *Actinoceras* and *Huronia*. In *Actinoceras* (Fig. 88) the visceral cone seems to have been constricted

by the septa into a series of beadlike swellings. The wall of these was stiffened, and as the siphuncle gradually shrank

away from it towards the centre, the space between the two became filled with calcite. These structures are very peculiar and often puzzling, especially when the inner tubes are found apart from the outer shells; in *Huronia* from the Silurian rocks of North America they look like fossil backbones, whence one species is named *Huronia vertebralis*. Some of the shells of *Actinoceras* must have been immense, probably exceeding 10 feet (3 metres) in length, for there is exhibited the body-chamber of *Actinoceras giganteum*, which has a diameter of about 11 inches; and a huge fragment, the whole of which appears to be septate, measures 2 feet 5 inches in length, the diameter of the larger end being about 8 inches, that of the smaller about $4\frac{1}{2}$ inches. This genus, which possibly occurs in the Cambrian, ranges through the Ordovician, Silurian, and Devonian to the Carboniferous Epoch.

Many of these Palaeozoic cephalopods are peculiar in that, after the shell has swollen out somewhat rapidly, perhaps to accommodate the ripening eggs, it again contracts in diameter, and not only this but in some genera the edges of the shell close over the opening of the body-chamber, leaving only narrow apertures. *Poterioceras* is one of the simpler types. The shell is pear-shaped, the earlier part being narrow and divided into chambers perforated by a siphuncle which is somewhat inflated between the septa; the upper and larger portion contained the animal. The whole shell is usually slightly curved, and its aperture not closed in. Fine examples of this genus come from the Carboniferous Limestone of Ireland. It must have attained considerable dimensions, for an example of *Poterioceras cordiforme* from the red Carboniferous Sandstone of Closeburn, Dumfriesshire, is 9 inches long and $7\frac{1}{2}$ inches in its greatest diameter. The shells of the Silurian Gomphoceratidæ are more egg-shaped and the opening is narrowed to a T-shape by the ingrowth of the margin (Fig. 89). The ends of the crosspiece and upright of the T are widened, and we may suppose that through the lower opening the funnel could eject its stream of water while some arms could emerge through the upper paired openings. Some allied



FIG. 89.—Three-lobed aperture.



FIG. 90.—Four-lobed aperture.

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1.

forms had a larger number of paired openings and could, one supposes, stretch out more arms (Fig. 90). *Ascoceras*, which occurs in the Ordovician of North America and the Silurian of Europe, especially Bohemia, had a curious life-history. This may be followed in the enlarged and diagrammatically coloured model which is exhibited. Beginning with a narrow tubular shell, divided by transverse septa, and having a simple siphuncle near the margin (Fig. 91 *F*), it suddenly swelled out like a *Poterioceras*. This gave more

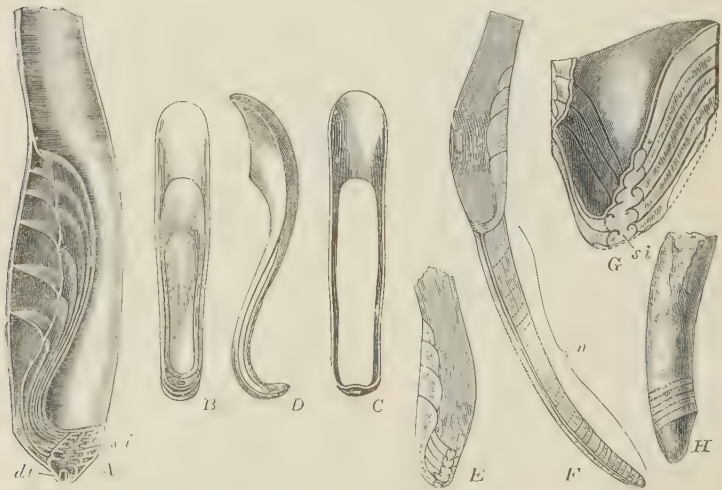


FIG. 91.—Ascoceratidae. *A*, upper part of shell of *Ascoceras manubrium*, cut down the middle, showing the upward-curved septa on the left; *B*, *C*, *D*, large curved septa of *Ascoceras fistula*; *E*, upper part of shell of *Ascoceras decipiens*, with septa of ordinary type formed after the deposition of the upward-curved septa; *F*, the shell of the same species completed, showing the simple nautiloid portion (*n*); *G*, *H*, fragments of an allied form, *Choanoceras*. (From Foord, after Lindström.)

room for the visceral cone with its contained genital glands, and naturally changed the character of the septation (Fig. 91 *A*, *F*). The body now had so much room that it ceased to advance to any great extent. On the contrary, as the animal grew older its body contracted, and first the opening of the body-chamber narrowed somewhat. Then the visceral hump shrank a little at its end, but more at the side, much as it did in the early stages of *Endoceras*. Thus the septa now produced remained close together at the apex of the body-chamber, and the siphuncle between them was swollen

as in *Poterioceras* (Fig. 91 *A*). But on one side the septa bent upwards, shutting off curved chambers at the side of the shell (Fig. 91 *B, C, D*). Sometimes the hinder part of the visceral cone shrank a little more and again formed some ordinary septa above these curiously curved ones (Fig. 91 *E*).

Simpler forms of straight or slightly curved shell, with transverse septa, the siphuncle near the centre, and a plain opening in the body-chamber, are grouped under the name *Orthoceras* (Fig. 80). Shells of this nature are found in all rocks from Cambrian to Trias, but especially in those of Silurian age. Some of them were several feet long. Among the many species exhibited one may note the common *O. ludense* from the Lower Ludlow beds; several from Bohemia, among which is *O. truncatum*, a form that seems to have made a practice of dropping the earlier chambers and sealing up the broken end of the shell with a plug of shelly substance; some polished sections from the Middle Devonian limestones of South Devon; and elongate shells, such as *O. gracile*, from the Lower Devonian of Nassau. Of Devonian age are probably the large specimens of *O. chinense*, known to the Chinese as "Pagoda stones," from the belief that they are formed underground where the shadow of a pagoda has fallen upon the surface. Polished slabs of rock containing these and other species of *Orthoceras* are on the wall by the door.

Slightly curved forms of simple Nautiloid type were formerly grouped under the name *Cyrtoceras*, but these are now distributed among several genera of early Palaeozoic age, the name *Cyrtoceras* being restricted to a purely Devonian genus. At an early period appear more closely coiled shells. Several in which the coils or whorls of the shell were scarcely, if at all, in contact, were formerly grouped as *Gyroceras*; but these also are now placed in several distinct genera. In some the earlier coils are close, but the last formed part of the shell is less close, as in the Silurian *Ophidioceras* (Fig. 92 *a*), or even straight, as though unwound, as in the Ordovician *Lituites*. In these two genera the shell aperture is contracted. In *Trochoceras* also the shell is not closely coiled, its special feature, however, is that the coils are not in one plane, but rise in a spire, something like a snail-shell. Beginning in the Cambrian, this genus lasts to Devonian times, but is most abundant in the Silurian rocks of Bohemia, England, and the United States. *Trocholites*, an Ordovician genus from North America, Europe, and India,

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2.

has three or four whorls closely coiled in one plane. The Ordovician and Silurian rocks of Bohemia furnish several specimens of a flat closely coiled shell, called *Barrandeoceras*, after the great palaeontologist of Bohemia; an example from Dudley is also shown.

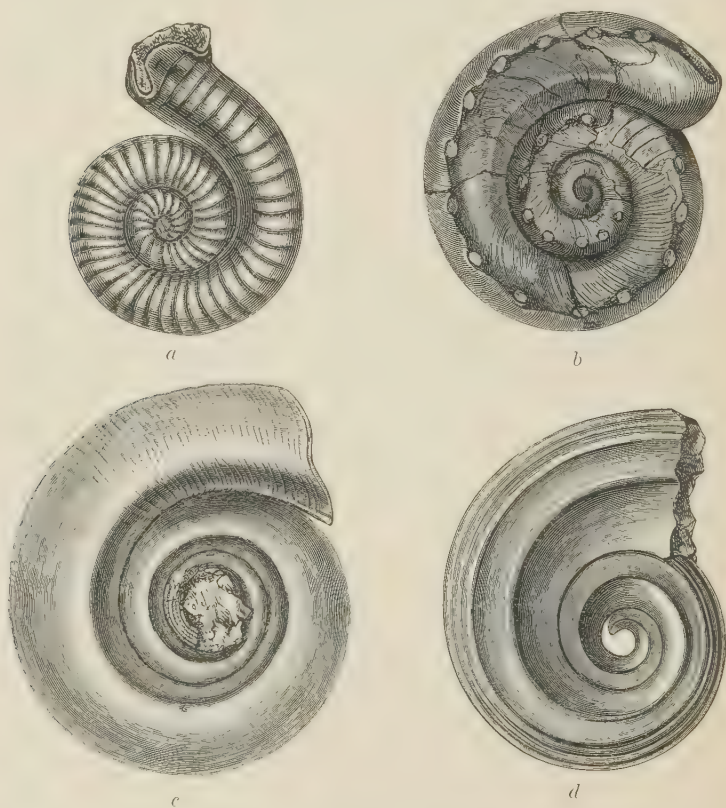


FIG. 92.—Palaeozoic Nautiloidea. *a*, *Ophidioceras simplex*, Silurian, Bohemia. *b*, *Hercoceras mirum*, Devonian, Bohemia. *c*, *Apheleceras mutabile*, and *d*, *Vestinautilus multica rinatus*, Carboniferous Limestone, Ireland. All slightly less than natural size. (From Foord.)

The coiled cone of the preceding shells is generally circular or elliptical in section, and has a smooth or slightly ornamented surface. There are others in which the cone is flattened or grooved, and the surface bears more marked ornament. Thus *Trigonoceras*, found in the Carboniferous

Limestone of Ireland, has its outer face so flattened that the cone is almost triangular in section. *Heroceras*, from the Devonian rocks of Bohemia, has a row of projecting tubercles arranged along its length; the shell is not very closely coiled, and its aperture is partly closed (Fig. 92 *b*). The Carboniferous shell *Apheloceras* is flattened, and so loosely coiled that there is usually an open space in the centre; ornament is often well marked on the inner whorls, but dies away, and gives place to transverse lines of growth in the later formed part of the shell (Fig. 92 *c*). The cone is sometimes grooved along its length, but such grooves are more pronounced in its contemporary, *Vestinautilus* (Fig. 92 *d*). Blunt tubercles are sometimes found on the sides of *Tremnocheilus*, which occurs in Devonian, Carboniferous, and Triassic rocks, and has a flattened outer face with angular sides. *Pleuronautilus*, which lasts from Devonian to Triassic times, is remarkable for its tubercles and transverse ribs, more like the ornament of an ammonite.

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The Carboniferous *Asymptoceras* has a smooth cone, widening rapidly, and with the margin of the aperture drawn out into a narrow projection on each side; its septa are simple as in *Nautilus*, but the siphuncle is near the margin. In *Subclymeia*, on the other hand, the sutures are so folded as to resemble those of some goniatites.

Table-case
2.

From the Triassic Limestones of the Austrian Alps are shown a number of shells, generally resembling that of the recent *Nautilus*, but separated by various minor differences. Even more like the modern *Nautilus* are the shells of Jurassic age. Among these is a specimen of *Nautilus clausus* from the Bajocian rocks, near Caen, showing impressions of the shell-muscles. A large *Nautilus ornatus* from the Inferior Oolite of Sherborne, Dorset, shows the rapidly widening cone, the lines of growth, and longitudinal grooves. The Gault furnishes several nautili in which the shell is well preserved, and in a young shell of *Nautilus semiundatus*, from the Upper Greensand of Warminster, the iridescence of the mother-o'-pearl septa may still be seen. This last species often attains a great size, as shown by specimens in the Wall-case. From the Upper Cretaceous Limestone of Lebanon comes *Nautilus libanoticus*, in two specimens of which the jaw-beaks may be seen. The nautili of the Chalk are often large, but the internal casts are usually all that is found.

Table-case
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Between
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Although it used to be said that the genus *Nautilus* persisted without change from early Palaeozoic times to the

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present day, closer study has disclosed many differences between the Palaeozoic shells and those of the modern nautilus. Even the Mesozoic shells are not really the same, and not until Tertiary times do shells occur that can with more justice be referred to *Nautilus* as now restricted. In the London Clay many of these are well preserved and show the internal structures; among them *N. imperialis* often attains great size. *Aturia*, of which specimens from Eocene, Oligocene, and Miocene rocks are shown, differs from *Nautilus* in the folding of its sutures, well seen in *A. ziczac*.

Further information concerning the fossil Nautiloidea in the Museum is given in the first two volumes of the "Catalogue of the Fossil Cephalopoda" issued by the Trustees in 1888-91.

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Order—**AMMONOIDEA**. One of the earliest straight-shelled forms that can without doubt be referred to this Order is the Devonian *Bacrites* (Fig. 81 *k*), in which the septa are still unfolded, but which has a protoconch (see model, Table-case 1) and its siphuncle marginal, i.e., near the outer shell-wall. We have already seen, in such a form as *Mimoceras compressum* (Fig. 81 *n*), how the straight shell became coiled first in its old age, and how in more advanced forms the coiling began at an earlier and earlier stage of the life-history, until even the protoconch was affected by it. In many of the earlier Ammonoidea the protoconch can still be seen distinctly (Fig. 93 *a*), being uncovered by later whorls,

Table-case
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Mimoceras compressum (Fig. 81 *n*), how the straight shell became coiled first in its old age, and how in more advanced forms the coiling began at an earlier and earlier stage of the life-history, until even the protoconch was affected by it. In many of the earlier Ammonoidea the protoconch can still be seen distinctly (Fig. 93 *a*), being uncovered by later whorls,

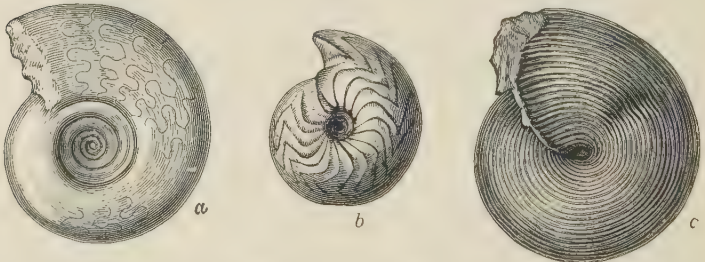


FIG. 93.—Goniatites. *a*, *Pronorites cyclolobus*, and *b*, *Glyphioceras sphaericum*, Carboniferous Limestone, England. *c*, *Agathiceras Suessi*, with shell preserved, Permo-Carboniferous, Sicily. Natural size. (From Foord and Crick.)

and its globular shape is apparent. In others the shell soon became more tightly coiled (Fig. 93 *b*), till the protoconch is hidden by subsequent whorls (Fig. 93 *c*). As the shell

became coiled, its septa were thrown into folds, but these were generally of a relatively simple character with an angular suture (Fig. 93 *b*), whence these forms are collectively known as **Goniatites**. They are usually smooth, or with only fine lines of growth, rarely with tubercles or ribs. The goniatites are mostly of Devonian and Carboniferous age, but also occur in the Permian, after which they give place to the Ammonites. Among the genera here exhibited may be noticed the above-mentioned *Mimoceras*, and *Agoniatites fecundus* also showing the uncoiled initial portion. Most of the Devonian goniatites are from Germany, but some species have also been found in this country. Thus there is a *Tornoceras* from the Middle Devonian of Devonshire, and *Glyphioceras intamescens* from the Upper Devonian of that county. Among the Upper Devonian specimens from Germany are several aptychi. Some Devonian genera form a special group, distinguished by having the siphuncle on the inner side of the whorl. The best known of these is *Clymenia*, and a thin section here exhibited shows this character plainly. Greater complication is noticeable in several of the Carboniferous goniatites. Here, for instance, are the closely coiled *Glyphioceras* (Fig. 93 *b*) and *Brancoeras*, *Gastrioceras* with tubercles, *Pericyclis* with transverse ribs, and *Prolecanites* and *Pronorites* with many-lobed sutures (Fig. 93 *a*). Near the last is the tiny *Dimorphoceras discrepans*. The goniatites are fully dealt with in Vol. III. of the Catalogue of Fossil Cephalopoda (1897).

The transition from Goniatites to **Ammonites** took place gradually along many lines, which are being worked out by a study of the Triassic species. This study is based mainly on the complications of the suture, which are far too intricate to receive further explanation in this place. Broadly speaking, it is possible to trace lines of descent with some exactness, owing to the fact that each individual shell in its early stages still possesses the structure that characterised its adult ancestors. This is indeed only one instance of a general principle of growth affecting most living beings; but the principle can be more easily applied in the study of these coiled shells, since the early stages are always preserved and can often be clearly seen. We have, for example, already noticed how the straight *Bactrites* stage is repeated in *Mimoceras*. It is often found that two species closely resembling one another in adult stages differ so greatly in their earlier stages as to lead to the conclusion that they

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have descended from totally different ancestors, and they may thus be placed in distinct genera, perhaps in distinct families. Unfortunately this method of study has not yet been pursued long enough for investigators to have settled the numerous problems presented by the very large numbers of these fossils; nor are the solutions that have hitherto been published always found to agree. Hence the classification and nomenclature of the ammonites has for some years been in a state of transition, to the great perplexity of geologists who wish to use these widely-distributed fossils for the identification of various strata and to quote names long familiar in that connection but now requiring emendation. It is impossible to alter the arrangement and naming of a great exhibited series like that of the British Museum to accord with a rapidly advancing classification. Those important questions must be studied in original memoirs, and these pages can only mention a few of the more conspicuous specimens.

The smaller ammonites in the Table-cases are arranged for the most part under the geological Ages, the foreign specimens of each Age being placed in the same Case as the British ones. The larger specimens in the Wall-cases begin with Liassic forms in Cases 12 and 11, pass to Bajocian in 10, and Oxfordian in 9; then, crossing the Gallery, continue with the uppermost Jurassic in Case 6, Lower Cretaceous in 5, and Upper Cretaceous species in 4 and 3. We begin with the oldest.

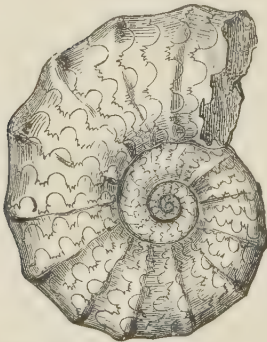
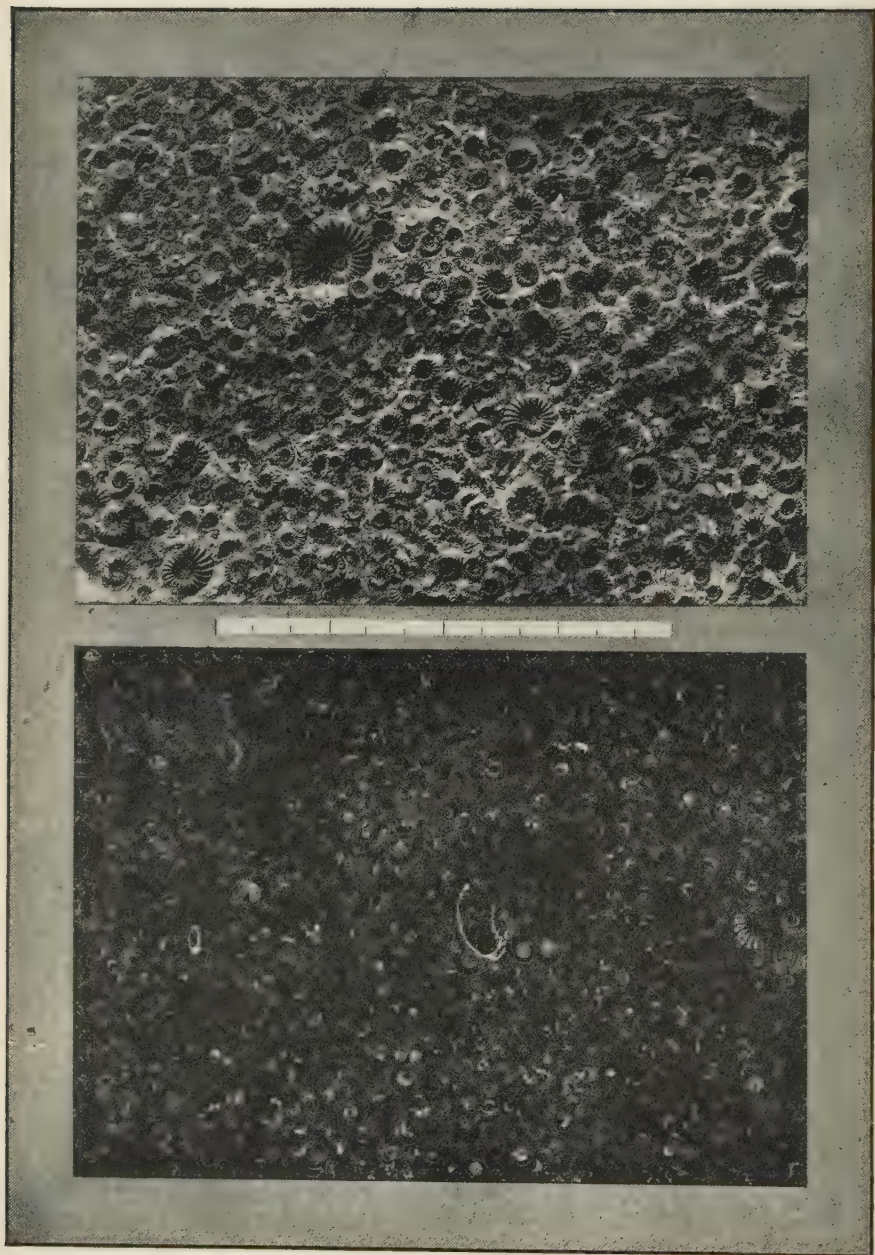
Table-case
5.

FIG. 94.—*Ceratites nodosus*
from the Muschelkalk.

From the Himalayan Trias are shown *Ptychites*, *Carnites*, and *Gymnites*, smooth shells, with sutures not far removed from those of goniatites. Among many specimens from the Upper Trias of Hallstadt in Austria, *Monophyllites* and *Rhacophyllites*, which have primitive sutures with leaf-like saddles, start the line of Phylloceratidae. In *Pinacoceras Metternichi*, on the other hand, the sutures have already acquired an extraordinary complexity, as best shown in some large specimens and a section in Wall-case 12. Sutures of rather simpler type are clearly shown in specimens of *Paracladiscites multilobatus*. From St. Cassian in the Tyrol come the roughly-ridged shells



AMMONITE MARBLE.

Marston Stone, from the Lower Lias near Yeovil, full of *Amblyoceras planicosta*.
The same Rock cut and polished.

of *Trachyceras* *Lon* (Fig. 95 *a*), marking a well-known horizon rich in fossils. *Ceratites* with its many rounded saddles, recalling *Prolecanites*, is also characteristic of the Trias (Fig. 94); a section of *C. nodosus* shows how the septa are at first concave as in older forms and then become convex towards the shell-aperture, as in ammonites generally. In *Arcestes intuslabiatus* the periodical constrictions of the coiled cone provoke enquiry as to their cause.

Passing to the Lias, one notes many type-specimens of species founded by the Sowerbys and by T. Wright, as well as examples of the ammonites that give their names to the successive horizons or zones into which the Lias has been divided. Of these the oldest is *Psiloceras planorbis*, the earliest English ammonite; beginning with slightly ribbed whorls, it reverts in the adult to the smooth shell of the older types. A fine slab covered with iridescent shells of this ammonite is placed on the wall. Among the British specimens from the Lower Lias, an example of *Liparoceras heterogenes* [C 1870] shows ribbed inner whorls like those of the adjoining *L. capricornu*, and outer whorls with tubercles, as in *Liparoceras striatum*. Such changes from smooth to ribbed, from ribbed to tuberculate, characterise many ascending lines of ammonite evolution. Here are to be seen shells of *Amblyoceras planicosta*, of which a thick bed was formerly worked as an ornamental marble at Marston near Yeovil. Slabs of this, showing weathered and polished surfaces, are placed on the adjoining wall (Plate VII). The larger specimens from the Lower Lias include a very fine example of *Coroniceras Bucklandi* showing the coronet of blunt spines from which the genus takes its name. Near this is a large *Asteroceras stellare* from Lyme Regis, cut in half and showing the chambers dislocated during fossilisation. *Asteroceras obtusum* shows the keel and the simple suture contrasting with the rather complex one of *Coroniceras*. Here is a *Deroceras armatum* with its big spines. Above are some large specimens of the rare *Vermiceras Conybearei*. Between the cases is the largest known Lias ammonite, about 1 metre (3 feet 4 inches) in diameter, possibly an old individual of the last species. Among species from the Middle Lias a noteworthy one is *Lytoceras jimbriatum*, with sharp ridges at intervals indicating that from time to time the aperture of the shell flared outwards, for reasons at which we can only guess (Fig. 95 *c*); these flares cut across the ordinary fine ribs of the shell; in

Gallery
VII.

Table-cases
6 & 7.
Wall-cases
12 & 11.

Between
Wall-cases
11 & 12.

Table-case
6.

Between
Wall-cases
12 & 13.
Wall-case
12.

Table-case
7.
Wall-case
11B.

Gallery
VII.

Lytoceras lineatum this habit was again lost, especially in old age, and only the fine ribs are seen. The two species *Amaltheus margaritatus* and *Paltopterocheras spinatum* should be noted for their peculiar ornament, and because they are characteristic of the Marlstone.

Among specimens from the Upper Lias the black ammonites from Whitby catch the eye. They include the

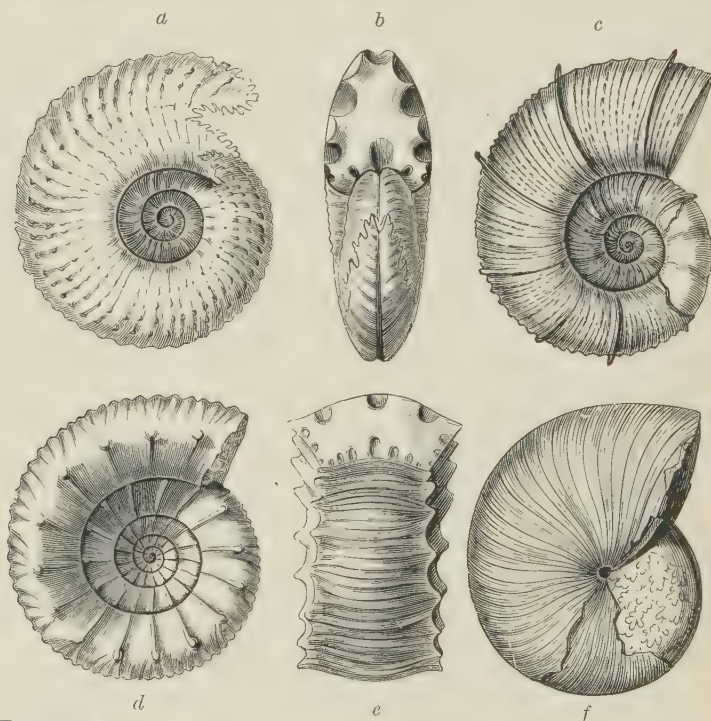


FIG. 95.—Ammonites. *a*, *Trachyceras Aon*, Upper Trias, side view. *b*, the same, front view, showing folded septum. *c*, *Lytoceras fimbriatum*, Middle Lias. *d*, *e*, *Coeloceras Blagdeni*, Inferior Oolite. *f*, *Phylloceras heterophyllum*, Upper Lias, shell partly removed to expose sutures. Less than natural size.

Table-case 7. primitive form *Cymbites carinatus*. Close by is the type-specimen of *Harpoceras falciferum*. An example of this species in the Wall-case has an aptychus in the body-chamber. Here, too, are large specimens of *Phylloceras heterophyllum* in section, as well as polished ones showing the foliated sutures (Fig. 95 *f*).

Wall-case
11A.

The Oolitic series includes *Macrocephalites* from India, and various genera from the Bajocian rocks of Calvados and the corresponding Inferior Oolite of this country. A specimen referred to *Stepheoceras Brodiaei* has a furrow down one side of the last whorl, the result apparently of injury to the secreting surface. The shell of *Cadomoceras cadomense* is eccentrically coiled, and has projecting ears at the sides of its aperture. *Haplopleuroceras subspinum* is remarkable as repeating the general form of *Pallopleuroceras spinatum* in the Middle Lias; this is one of those similarities of form in different genera that has led to so much confusion in classification. Here we may note a fine aptychus from the Stonesfield Slate, and a beautiful *Stepheoceras* from the Great Oolite of Minchinhampton. The ensuing Cornbrash furnishes good specimens of *Macrocephalites*. The larger ammonites from the Lower Oolites include fine examples of species giving their name to well-known horizons, such as the type-specimens of *Ludwigia Murchisonae* and *Stepheoceras Humphriesianum*, also *Parkinsonia garantiana*, *Strigoceras Truellei*, *Coeloceras Blagdeni* (Fig. 95 d), and *Parkinsonia Parkinsoni*. There are some very large specimens of *Parkinsonia dorsetensis* and others, cut down the middle, or polished to show the sutures. The type-specimen of *Fontannesia Boveri* from the Inferior Oolite of Bradford Abbas preserves its long ears, and here is also the type-specimen of "*Ammonites*" *Tessonianus*, d'Orbigny, from the Tesson collection. Among Oxfordian species the well-known *Cardioceras cordatum* repeats the general form of *Amaltheus margaritatus*, although derived from quite a different stock. Very fine series of this genus and of *Cudoceras* are in the Wall-case. The Callovian series furnishes several characteristic genera, among them the highly-ornamented *Cosmoceras*. Many Oxfordian species of this genus have very long processes or ears from the sides of the aperture. From the Oxford Clay of Wiltshire come large specimens of these as well as of *Proplanulites Koenigi* with a smooth senile stage.

The Coral Rag of England is noted for the internal casts of the chambers of ammonites, from which the shell has been dissolved away. These belong mostly to *Aspidoceras perarmatum*, of which some specimens from Brora, in Sutherland, are also shown. Numerous aptychi are found in the Kimmeridge Clay, especially at Ely, and the same forms occur in connection with their ammonites in the contemporaneous Solenhofen Stone. Near these are examples

Gallery
VII.
Table-case
8.

Wall-case
10.

Wall-case
9.

Table-case
9.

Wall-case
9.

Table-case
9.

Wall-case
9.

- Gallery VII. of *Holcostephanus* from the Portlandian near Moscow, showing the iridescent shell. The large *Holcostephanus gigas*, and the still larger *Perisphinctes giganteus*, from the Portland Stone of England are in the Wall-case. A small specimen of the latter species had the shell turned into silica, and the infilling limestone has been dissolved out, exposing the shape of the septa and the position of the siphuncle.
- Wall-case 6.
- Wall-case 5. The Lower Cretaceous rocks have not furnished many ammonites, but the large *Parahoplites Deshayesi* from the Lower Greensand carries on the general plan of the genera just mentioned. Other new genera appear in the series from the Albian of Escagnolles (Var), and from the coeval Gault of Folkestone. The iridescent appearance of these and other ammonites previously noticed is due to the solution of the outer layers of the shell, by which the inner nacreous layers are exposed. Here we meet with *Hoplites*, characterised by a broad groove on the outer margin of its shell, similar to that previously seen in the otherwise unlike *Schlotheimia* of the Lower Lias and *Parkinsonia* of the Lower Oolites. The specimens of this genus from Folkestone form a series illustrating the decline of ornament from tuberculate, through ribbed, to smooth. Similarly *Mortoniceras* shows a decline from highly tuberculate to ribbed. *M. rostratum* marks a wide-spread horizon in the Albian, and there is a splendid series of it from both Gault and Upper Greensand, preserving the long rostrum at the shell-aperture. *Phylloceras Guettardi* and several species of *Holcodiscus* show periodical constrictions of the shell-aperture. The specimens from the Cambridge Greensand are derived from the underlying Gault, and those from the Red Chalk seen in the next case are also of that age.
- Table-cases 10, 11, & 12.
- Wall-case 5. The Cenomanian forms in the Table-case include the characteristic *Metacanthoplites rotomagensis* from Rouen, *Brahmites* from Pondicherry, and *Pachydiscus* from various European localities. The Upper Cretaceous rocks of South Dakota yield specimens of *Placenticeras* with elaborate sutures. *Tissotia*, on the other hand, from the Senonian of Algeria, shows that return to a Ceratite form of suture which is found in many late Cretaceous ammonites. Among the British specimens from the Chalk Marl and Chalk are many figured in D. Sharpe's monograph published by the Palaeontographical Society. Those from the Chalk Marl include a fine series of *Schloenbachia* ranging from the tuberculate *Schloenbachia Coupei*, through the more or less ribbed
- Table-cases 12.
- Table-cases 12 & 13.

S. varians, to the smooth *S. Goupilianus*. This again illustrates the change of ornament characteristic of a declining series. Among the larger specimens the most noteworthy are *Puzosia Austeni*, *Pachydiscus peramplus*, and *Pachydiscus leptophyllus*. Some specimens clearly show the complex suture of this last, but the most interesting is the very large one from Rottingdean, 3 feet 8 inches in diameter; the rapid increase in the width of the coiled cone may be contrasted with the very slow increase in the large Lias specimen opposite. The largest known ammonite is *P. seppenradensis*, from the Lower Senonian of Westphalia, with a diameter of about 2 metres (6 ft. 8 in.). A plaster reproduction of it is fixed at the north end of the Gallery.

We have already noticed the changes in ornament that characterise ammonite races as they advance to and recede from the acme of their development, and we have seen how the suture likewise becomes more complex and then returns to a simpler form. There is yet another and more obvious change. Just as the ascending stocks, beginning with straight forms, gradually coiled the shell more and more closely, so, having reached their acme, they begin to uncoil and may ultimately return to a straight condition, if they do not previously become extinct. Further, instead of merely unwinding, they may lose the regularity of the coil and become wound in an asymmetrical spire or turret, like that of most gastropod shells. Already in Triassic times the *Ceratites* (using the term in a broad sense) show all these retrogressive changes, ending in the straight *Rhabdoceras*. Of the various ammonite families that passed into Jurassic and Cretaceous times, the *Stepheoceratidae* gave off a degenerate branch so early as the Bajocian Age. The eccentric *Calomoceras* has already been noticed, and here are exhibited the further uncoiled *Spiroceras bifurcatum* and similar forms, which led to the straight *Baculina* of the Callovian.

It was, however, chiefly towards the close of the Cretaceous Epoch that all the persisting races entered on this degeneration. Names have been given to the various stages of uncoiling, such as *Crioceras*, in which the whorls are partly separate (Fig. 96 a); *Macroscaphites* with the last whorl bent slightly back and then returning on itself (Fig. 96 d); *Scaphites* with a somewhat closer coil to start with and a more rapid return (Fig. 96 f); *Hamites*, which starts with a small coil, then goes straight for some distance,

Gallery
VII.

Wall-case
4B, 4A.

Between
Wall-cases
3 & 4.

Table-case
8.

Table-cases
14 & 15.
Wall-case
3.

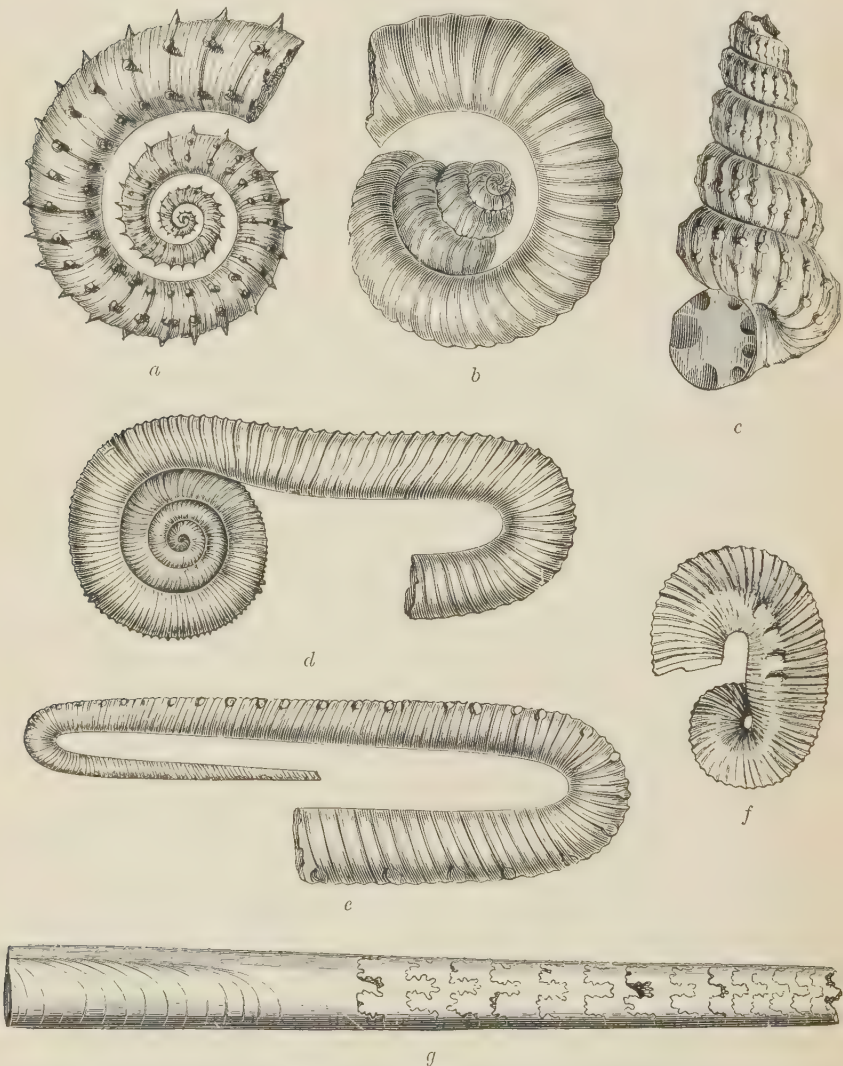


FIG. 96.—Uncoiled and Asymmetric Cretaceous Ammonoidea. *a*, *Crioceras Emerici*, Neocomian. *b*, *Heteroceras Emericianum*, Neocomian. *c*, *Turritites catenatus*, Albian. *d*, *Macroscaphites Ivanii*, Neocomian. *e*, *Hamites elegans*, Albian. *f*, *Scaphites Hugardianus*, Albian. *g*, *Baculites anceps*, Danian. All less than natural size.

then returns for a longer distance, and ends straight after yet another bend (Fig. 96 *c*); and *Baculites*, in which, after a small initial coil, the shell continues straight to its aperture right up to death (Fig. 96 *g*). By study of the ornament and suture, it has been found that these forms represent stages of degeneration common to more than one race, and therefore do not constitute true genera. Thus many of the Neocomian shells in the Crioceran stage are ribbed in the irregular manner characteristic of *Lytoceras*; see, for example, *C. villersianum* in the Table-case. Those named *Pictetia Astieriana* also show the peculiar Lytoceran suture. In many of those from the Speeton Clay, on the other hand, e.g. *C. quadratum*, the ribbing is very irregular, and appears to have been derived from such a form as *Perisphinctes* or *Holcostephanus*. The same appears to be the case with the large Aptian *Crioceras Bowerbanki* and its relative *Macrocephites grandis*, the earlier whorls of which resemble those of the Portlandian *Holcostephanus gigas*, while the later portion presents a remarkable exaggeration of certain ribs. In these massive shells may be seen a curious retention by the uncoiled portion of a character originally due to close coiling. The cone in the earlier Ammonoidea is circular or elliptical in section, but as they become coiled the inner side of the outer whorls is impressed or excavate, so as to fit closely over the inner whorls (Fig. 95 *b*); the closer the coil, the greater is the depth of the impressed zone. This impressed zone is clearly seen on the later whorls of many of these uncoiled forms and is clear evidence of their descent from more closely coiled ancestors. Eventually it disappears, and the long loops of a Hamite, for example, show no trace of it. In many shells called *Baculites*, the folded sutures alone distinguish the greater part of the shell from a smooth Devonian *Bactrites*; but even the sutures, as may clearly be seen in the specimens from the north of France, are much simpler than in most of the coiled or partly-coiled ammonoids. The shell-aperture is oblique, suggesting that the animal had given up swimming for crawling.

The history of the turretted or helicoid shells is of the same general character. There is, however, reason to suppose that the tendency to this asymmetry usually arose at quite an early period in the life-history instead of coming in with old age as did the uncoiling. Something of the kind was noticed in Palaeozoic nautiloids, and it may be supposed that the tendency was always present, especially in weaker

Gallery
VII.
Table-cases
14 & 15.
Wall-case
3.

Gallery
 VII.
 Table-case
 15.
 Wall-case
 8.

individuals, but was kept in check by the close coiling. Turretted forms appeared first in the Upper Trias (e.g. *Cochloceras*), but it was in the Cretaceous Epoch that they were first a large element in the fauna. *Turrilites* (Fig. 96 c) in the strict sense and various genera of similar form appear to be derived from such antecedent forms as *Cosmoceras* and *Douvillicerias*, which they resemble in ornament. In some of these the whorls are closer than in others. *Helicoceras* and *Heteroceras* (Fig. 96 b) begin as asymmetrical spirals, but turn off in a different direction in old age. They and some of the Hamites are supposed to be connected with *Acanthoceras*. The direction of the turretted coil varies: in the Senonian *Heteroceras polyplacum* from Westphalia it is dextral, as in most gastropods; in the Turrilites of the Chalk Marl it is generally reversed or sinistral; in those of the Gault it is indifferently dextral or sinistral in the same species.

The various changes in these Cretaceous Ammonoidea may be described as retrogressive, for they are in some respects a going back along the line followed in the previous evolution of the Order. They were followed by complete extinction, for the Order did not persist into the Cainozoic Era. Were these changes in accord with changes in the environment, and was the extinction of the Order due to inability to keep pace with change of conditions? Or were the changes inherent in the constitution of the ammonites, a necessary result of their previous history, and do they signify a true degeneration and decline, out of all accord with the surroundings? One fact not yet mentioned may have a bearing on this problem. It is that in some shells the last bend grew in such a direction that in old age its aperture was brought up against a preceding part of the shell, so that the arms of the animal can scarcely have emerged; by continuing its own growth, it seems that the individual killed itself. Did the race do the same?

Order **COLEOIDEA** or **BELEMNOIDEA**.—In modern times this has taken the place formerly occupied by the Ammonoidea and before that by the Nautiloidea. Whatever may be the affinities of certain straight-shelled Palæozoic cephalopods, the earliest fossils that show undoubted traces of the enclosing mantle are *Aulacoceras* and *Atractites* of the Upper Trias. These have guards, but the phragmocone is relatively large, and in the former retains traces of longitudinal ornament.

Wall-case
 8.

In the Lower Lias of Dorset are still found very large phragmocones, but other specimens show the Belemnite type fully developed, with pro-ostracum, ink-bag, and hooked arms. Of *Belemnites elongatus* there is the fine specimen described by Huxley in the Monographs of the Geological Survey and Sowerby's original specimen from Crick tunnel near Daventry. The Middle Lias of Charmouth has yielded the slender *Xiphoteuthis elongata*, also described by Huxley. From the Upper Lias of Alderton, Gloucestershire, comes a well-preserved pro-ostracum. A monster phragmocone of the Bajocian species *Belemnites giganteus* comes from Germany. The Oxfordian of Trowbridge and Christian Malford in Wiltshire furnishes a large series of *B. Owenii*.

Gallery
VII.
Wall-case
8.

Among Cretaceous belemnites, *Duralia dilatata* is remarkable for its guard, swollen in one direction and flattened in the other. *Actinocoma* is the usual form from Cenomanian to Senonian, being joined by the similar *Belemnitella* in the latter Age.

Table-case
16.

The belemnites did not die out at the close of the Cretaceous Epoch, but they changed in character. *Styracoteuthis orientalis* from the Eocene of Syria is still of the older type, but in most the guard was reduced in length, thickness, and calcification. *Vasseuria* from French Eocene rocks has such a slender yet relatively short guard. In *Beloptera* and *Belopteria* the guard is short and somewhat swollen at its end, which makes a slight angle with the phragmocone; in the former it expands at the sides into two wings. The latter genus is not far removed from the Miocene *Spirulirostra*, already described (Fig. 85 *b*). In a later genus *Spirulirostrina* (not exhibited) the guard is more reduced, and in the modern *Spirula* it has disappeared (Fig. 85 *c*).

Table-case
16.

Another line of evolution leads, as previously explained, from *Beloptera* to *Belosepia* (Fig. 85 *d*) of which many specimens from the London Clay and Bracklesham Beds, are shown. *Sepia* itself is exhibited from later Tertiary rocks (Fig. 85 *e*).

Wall-case
7.

Of those sheathed forms in which the calcification of the shell underwent a gradual reduction, the earliest known is *Phragmoteuthis* from the Upper Trias. The next in age is *Geoteuthis*, of which large specimens from the Lower Lias of Dorset are exhibited. These and the smaller specimens from the Upper Lias of Würtemberg and Normandy show an expanded pro-ostracum, divided lengthwise into three areas, and with no trace of a phragmocone. Many of these

Wall-case
7.

Gallery
VII.
Wall-case
7.

preserve the ink-bag, which in *G. brevipinnis* from the Oxford Clay of Christian Malford is sometimes of great size, while the ten arms are very short—an obvious correlation. From the Upper Lias are also shown the similar shell of *Teuthopsis*, and that of *Beloteuthis* strengthened by a median keel. Shells of generally similar character are found in *Cocconeuthis* [*Trachyteuthis*] from the Solenhofen Stone. An admirable specimen preserves portions of the mantle and side-fins, and has eight well-developed arms bearing suckers; the two long arms found in recent Decapoda may have been present but retracted. A very large shell of this genus is at the bottom of the Case. In *Plesiotheuthis prisca* from the same stratum the shell is reduced to a long narrow pen, with the side expansions at its hinder end and quite small. The same genus occurs in the Senonian rocks of the Lebanon, whence come *Plesiotheuthis Fraasi* and the allied *Dorateuthis syriaca* (Fig. 86 *b*), both with eight short and possibly two long arms.

Table-case
16.

A shell in which the phragmocone is still preserved, as in *Phragmoteuthis*, but in which the guard is reduced to a thin shiny coat, is that of *Belemnoteuthis antiqua* (Fig. 86 *a*). There is shown a fine series of this from the Oxford Clay, chiefly of Christian Malford (see p. 156). The ten short arms are well seen, and in one specimen seem to have caught a small fish. *Acanthoteuthis* from the Solenhofen Stone is said to have had a shell with more reduced phragmocone and larger pro-ostracum. Specimens are shown preserving the arms, eight or ten in number, with well-marked hooks; the mantle; and a membrane round the mouth like that of living Onychoteuthidæ. *Conoteuthis* (Fig. 85 *g*), of which fossils are shown from Neocomian, Aptian, and Albian rocks, had a small curved phragmocone, suggesting the end of the *Ommastrephes* shell (Fig. 85 *h*).

Wall-case
7.

The specimen of *Palaeoctopus Newboldi*, from the Senonian of Lebanon, is the oldest fossil Octopod. There is no evidence to show from which of the races just described it may have been derived. With the Octopoda, which are the most highly specialised of Mollusca, and furnish some of the monsters of modern seas, we reach the end of this sketch of extinct invertebrate animals.

APPENDIX.

AMONG recent additions to the exhibited series of Mollusca (pp. 122-144) are the following:—

Gallery
VIII.

Shells from various non-marine deposits of Cainozoic age in Germany, such as those in the Mayence basin. The genera exemplified include *Planorbis*, *Limnaea*, *Clausilia*, *Pomatias*, *Neritina*, *Unio*, *Corbicula*, and *Dreissensia*, with *Helix* and its allies.

Table-Case
next A3.

The evolution of form and sculpture is illustrated by continuous series of growth-stages in the modern *Melanopsis Parreysii*, peculiar to Hungary, and in its predecessors found in the Pleistocene deposits of that country. The specimens are arranged on the plan of Dr. Toth Mihaly, as advocated by S. Brusina (see "Mitt. Nat. Verein Steiermark," 1903, p. 101, and "Földtani Közlöny," 1905, p. 421).

Wall-case
1A.

Another small series purports to show the evolution of certain species of *Viviparus*. Specimens from the Pliocene rocks of Slavonia were originally studied by M. Neumayr, who found that specimens with more complicated sculpture occurred in the upper or newer part of the deposits, and appeared to be descended from the smooth forms common in the lower and older beds.

Between
wall-cases
2 & 3.

Traces of the original colour-markings are occasionally found in fossil shells (see p. 123). Others again sometimes show pearl-structures (see p. 135). Both these appearances have recently been studied ("Proc. Malacological Soc. London, 1907, 1908), and illustrative specimens are now exhibited.

Wall-case
3C.

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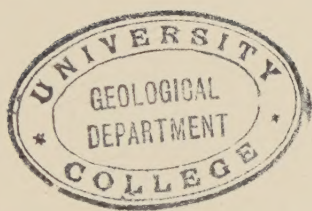
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